A SYSTEM FOR DESIGNATING MAP-UNITS ON ENGINEERING SOIL-MAPS

Donald R. Lueder, Research Engineer [a]

INTRODUCTION

In recent years, soil surveys have gained wide acceptance as a useful, and often necessary, phase of highway engineering. Considerable attention is now being concentrated on the problem which these large scale surveys have created, namely that of providing means by which the results of a survey can be effectively disseminated for intelligent, practical use.

The soil-map has proved to be a particularly suitable means for such dissemination. The simplest soil-maps merely delineate soil areas. The most effective soil-maps, however, also tend to describe conditions within the soil areas. This self-descriptive quality necessitates a logical conversion of soil information into map-units or designations. Such an operation is always difficult, sometimes critically so. The inclusion in a map-unit of all the varied soil information which is ordinarily available yields only a hodge-podge of data. Yet, map-units which contain only single groups of facts, such as geology or laboratory test results, do not give a sufficiently complete picture of the soil and its environment. The feasible methods lie between these two extremes.

One such method, which this paper describes, is based upon an initial selection for emphasis, of certain important items of soil information which are then converted into map designations according to a logical system which satisfies a number of practical criteria. The system has been developed for use in the preparation of an engineering soil map of New Jersey, a project which is under the joint sponsorship of the United States Bureau of Public Roads, the New Jersey State Highway Department and Rutgers University, the State University of New Jersey. The Joint Highway Research Committee, which has approved the report, feels that the system offers definite advantages. However, it realizes that changes may be desirable. Therefore, it believes that this report should be considered as a proposal, presented for the study, comment and revision of other organizations which are confronted with the soil-mapping problem.

[a] Joint Highway Research Project, New Jersey State Highway Department and Rutgers University, The State University of New Jersey, in cooperation with The United States Bureau of Public Roads.

SUMMARY OF PEDOLOGICAL CONCEPTS

During the last ten years, certain pedological concepts concerning soils and soil-development have been accepted and utilized by the highway engineering profession. According to a fundamental concept, soil is a natural, unconsolidated body of variable depth, differentiated into horizons which are composed of mineral and organic constituents, and which differ from the parent material in certain important respects. [1] Other important concepts assert that the development of this natural body is a result of physical and chemical weathering processes; that these processes are a function of certain coexistent, inde-

[1] This definition is derived from a more exact and inclusive definition by Joffe. *(1)* *Italicized numbers in parenthesis refer to bibliography at the end of this paper.*

pendent variables; and that the resulting development in depth, i.e. the soil profile, reflects both chemically and physically, the combined influence of such variables. The variables may be listed as: [2]

1. Climatic factors under which weathering has progressed (mainly precipitation and temperature).
2. Parent formation from which soil is derived.
3. Time that parent formation has been subjected to weathering.
4. Topographic position at which weathering has occurred.
5. Biotic factors under which weathering has progressed.

Any detailed discussion concerning the interplay of these primary variables and their effect upon soil-development is beyond the scope of this paper.[3] It is necessary only to review the characteristics of a soil-profile which reflect such an interplay. The proposed system of map-units has been developed in connection with a single type of such a profile. This profile is typical of those developed under forest or meadow vegetative cover, upon any type of parent material, under ranges of precipitation and temperatures which are characteristic of humid-temperate to humid-cool climates. It almost invariably consists of three general horizons[4] (Fig. 1):

1. A-horizon - often called the top-soil. This horizon includes surficial, organic accumulations, together with a depth of soil which has been subjected to weathering for the longest time. Many of the fine materials produced in this horizon by the processes of weathering have been subjected to a downward leaching action, leaving a generally silty residue.

2. B-horizon - a zone beneath the A-horizon which is composed of those weathered materials produced in the horizon itself, supplemented by an accumulation of residue leached from the A-horizon. Due to the lodging of these transported fines, the B-horizon is relatively (within the profile) compact, plastic, and colloidal.

3. C-horizon [5] - a relatively unaltered horizon which is often characterized by a high percentage of rock fragments, and which passes

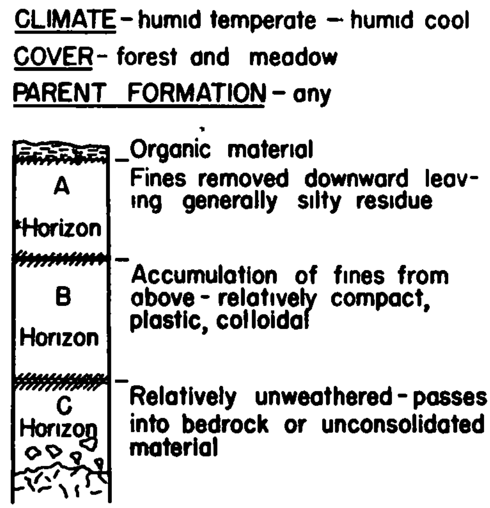

Figure 1. Diagrammatic Weathered Profile

[2] Indicative of references which discuss the primary variables in detail, are Joffe (*1*) and Jenny (*2*).

[3] For such a detailed discussion, see Jenny (*2*). Insofar as they are pertinent, brief considerations of climate, parent material, position and time are included in a discussion of the proposed system which forms the latter part of the presentation.

[4] For an excellent discussion of pedology and the history of pedology, see Joffe (*1*).

[5] This horizon is usually called the parent material. However, there seems to be some disagreement over the meaning of parent material. This is especially true for residual soils. Some opinion considers the bedrock as the true parent material, while other opinions characterize the rotten layer just above bedrock as the parent material. Jenny (*2*) defines the parent material as "the initial state of a soil system". This appears to be a wise definition. In this paper, the parent material refers to the material from which the significantly altered horizons develop, i.e. rock plus rotten rock in the case of residual soils.

into unweathered bedrock or transported formations.

SOIL CLASSIFICATION AND SOIL SURVEY

The highway engineer has been interested for some time in the formulation of a practical system for soil appraisal which will incorporate the factors that bear directly upon his problem. The initial efforts to formulate such a system have centered around the development of laboratory classification systems. Most of these systems have differentiated soils on the basis of their physical laboratory indices. Soils having similar indices have then been grouped together. The points of similarity have, of course, depended upon the purpose and comprehensiveness of the system. In all cases, however, the correlation of indices with field soil-behavior has enabled the systems to be used with considerable success.

In the majority of these systems, the classification tests are performed on the soil in a highly disturbed, or at least removed, state. Because of this, a most important factor which might be termed the "factor of environment", is disregarded. Many engineers can testify that soils with almost identical test constants and classifications may react quite differently in the field, even if subjected to equal traffic volumes and loads acting upon similar structures. The essential reason for these differences in performance is that the soils are characterized by different natural environments. The effect of such factors as parent material, topographic position, profile development, etc. have caused internal modifications which are significant insofar as the engineering characteristics of the soils are concerned. Realizing this, many engineers are convinced that soils must be considered in relation to their environment, and that areal studies of in-place conditions are particularly valuable.

To this end, many State highway departments have instituted soil surveys which are designed to classify soils, not only by means of their physical indices, but also according to their position in the terrain. A recent survey has indicated that some 28 States require detailed soil-surveys prior to the construction of high-type roads.[6] These surveys are based upon the reasonable assumption that "soils having similar profiles (and environments) require similar engineering treatment . . . and occur in similar types of landscape".[7] Many variations in the method of soil-survey are now in use (see reference below), and improvements in technique are constantly being reported. It is reasonable to assume that these improvements, together with time-saving methods such as airphoto interpretation,[8] will tend to increase the accuracy, scope, and comprehensiveness of such procedures.

ATTRIBUTES OF MAP-UNIT SYSTEMS FOR SOILS

Although the methods of accomplishing the soil-survey are many in number, the systems used to present the acquired information in the form of usable soil-maps are even more variable. If soil surveys are to increase in number and extent, and if the highway engineering profession is to derive maximum benefit from the assembled information, it appears highly desirable, if not imperative, that some standardized system of map-units be devised. Much of science's progress has occurred because qualified specialists have been able to discuss their problems and techniques with reference to well-established, widely accepted bases of classification. Thus, the pedologists have the Glinka soil classification, the climatoligists have the Koppen notation, the geomorphologists have the Davis nomenclature,

[6] See reference (*4*). Discussions of some representative methods can be found in references (5), (6), (7), (*8*), (*9*) and (*10*).

[7] Brackets are the writer's.

[8] Excellent discussions relating to the airphoto method can be found in references (*11*), (*12*), (*13*) and (*14*).

etc. It is believed that the effective interchange of ideas, and the progress of discussion, comparison, and research in the highway field, will be facilitated to a significant degree by the adoption of a standardized system of map-units. It is almost certain that such a system will facilitate the exchange and dissemination of constructional experiences and techniques.

Before discussing any particular type of map-unit system, it appears desirable to investigate those characteristics of a system which will make it effective in the preparation and use of engineering soil-maps. The following attributes are suggested as being a minimum:

1. Simplicity - The system should be relatively easy to learn, remember, apply and interpret. This should not imply that the learning be accomplished without effort, but rather that the effort should be justified by the benefit derived.
2. Conciseness - The system must provide concise identifications to satisfy the requirements of simplicity, and allow small areas to be properly labelled.
3. Talkability - The map-units must be of such nature that they can be used in conversation, research and publication. It is comparatively easy to devise a complicated code which will allow for every variable within a given soil-occurrence, but such a system defeats its purpose because it cannot be thought of and used as an entity.
4. Uniformity - Identical map-units should be provided for soils which are identical within the limits of the system.
5. Informativeness - The map-units should convey enough information concerning a soil area to allow an immediate rough evaluation of the soil's environment, major properties and field characteristics.
6. Reproducibility - The system should be adaptable to easy, rapid, economical reproduction on common highway base-maps. Colors and complicated patterns, while an aid, should not become a necessity.

Each of the above attributes imposes severe restrictions upon any attempts to devise a satisfactory system of map-units. Probably the most troublesome requirements are those which relate to conciseness and informativeness. It is difficult to conceive of a system which provides brief symbols that, nevertheless, convey a considerable amount of information. For instance, if one were asked to list those soil-characteristics which are desirable in a map-unit system, the following enumeration might result:

1. Climatic influences and corresponding profile type
2. Origin of parent formation
3. Type of parent formation
4. Physical characteristics of parent formation if consolidated:
   a. Hardness (and other engineering properties)
   b. Orientation
   c. Structure
   d. Depth below surface
5. Land form
6. Existence and characteristics of a significant underlying formation
7. General characteristics of the developed soil profile:
   a. Number of horizons
   b. Depth of horizons
   c. Predominant physical characteristics of each horizon
   d. Predominant mineralogical characteristics of each horizon (especially with regard to clay minerals)
   e. Predominant chemical characteristics of each horizon
8. Predominant existing drainage conditions
9. Associated engineering soil-problems

The inclusion of the above information in a mapping system which could also be characterized by the properties of simplicity and conciseness, presents difficulties which are obvious. Therefore, it is necessary to eliminate some of the listed factors. To preserve simplicity, conciseness, etc. and for various other reasons, most of which are indicated in the latter portion of the paper, all but the following factors have been eliminated in the proposed system:

1. Origin of parent formation
2. Type of parent formation
3. Land form (for transported materials only)
4. Existence of profile contrast
5. Texture of important horizons
6. General drainage conditions
7. Underlying materials (where important with regard to construction)
8. General engineering problems (by interpretation)

The mapping system hereafter described attempts to convert the above soil-information into a logical system of map-units. The system has been developed during the last two years for use in the preparation of an engineering soil-map of New Jersey. Using air-photo interpretation, supplemented by field, laboratory and reference work, the system has been experimentally applied to date over an area of some 1900 square miles. The parent formations included within this area are of sedimentary, igneous, metamorphic, glacial, marine and alluvial origin. The residual soils have been derived from shale, limestone, conglomerate, sedimentary complexes, basalt, diabase and gneiss. The non-residual soils have been derived from glacial ground moraines, terminal moraines, outwash, kames, eskers, terraces, and lacustrine areas, as well as from old drift (pre-Wisconsin); from old and recent alluvium; and from marine deposits of sand, silts, and clays. The basis for the inclusion of laboratory classifications is a file of test results on some 450 sample profiles.

The system will be described briefly, and without elaboration, in the next few pages. It will then be discussed in more detail. It is hoped that the description and discussion will be read with the following points in mind:

1. The method described has been used with, and is particularly adaptable to, the techniques of air-photo interpretation.
2. The method described is based upon humid-temperate to humid-cool climatic conditions. This does not invalidate the general technique for other climatic regions. It merely indicates that certain changes must be made within the framework of the whole.
3. The method described is of particular benefit when the soil-map is supplemented by a companion descriptive bulletin which, for each area, will include information not presented by the map-unit, as well as an amplification of the map-unit.

PROPOSED SYSTEM OF MAP-UNITS FOR SOILS

Climate - A consideration of climate is included in the discussion.

Origin of Parent Formation - The soils of any area which are to be identified by map units are first classified as:

1. Residual soils - derived from consolidated parent formations
2. Non-residual (transported) soils - derived from unconsolidated, or very weakly consolidated, mateerials

Residual soils are then differentiated, according to the origin of their parent formations, into the three geologic classes, each class being identified by an appropriate captial letter:

1. Sedimentary - S
2. Igneous - I
3. Metamorphic - MM

In a parallel fashion, the non-residual soils are differentiated according to the origin of their parent formations into the four geologic classes[9]:

1. Glacial - G
2. Alluvial - A
3. Windblown - W
4. Marine - M

Type of Parent Formation - Residual soils are differentiated according to the lithological character of the parent formation, i. e. shale, limestone, granite, gneiss, etc. Each of these lithological types is identified by a characteristic lower-case letter such as limestone (l), sandstone (s), shale

[9] It may be desirable to include the colluvial category (C) in some areas.

(h), granite (g) and gneiss (g). When these letters are combined with the proper letters of origin, characteristic symbols result - Sl (limestone), Ss (sandstone), Sh (shale), Ig (granite) and MMg (gneiss).

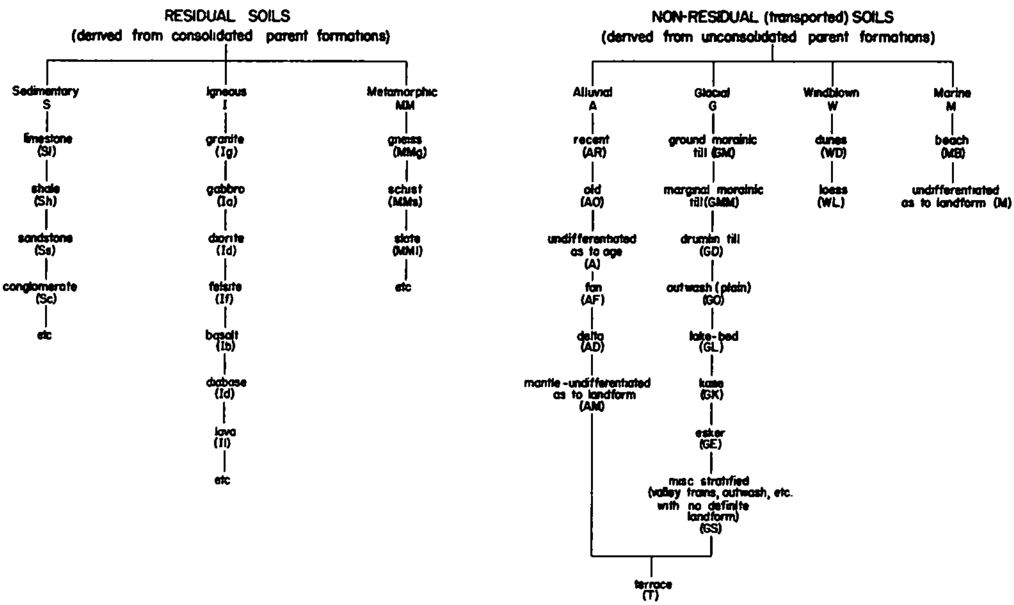

Figure 2. Origin and Type of Parent Formation

Non-residual soils are differentiated according to their types of landform. Each of these landform types is identified by a characteristic letter or letters, such as ground moraine (M), marginal moraine (MM), outwash plain (O), dunes (D), and fan (F). When these letters are combined with the proper letters of origin, characteristic symbols again result - GM (glacial ground moraine), GMM (glacial marginal moraine), GO (glacial outwash plain), WD (windblown dunes), AF (alluvial fan). A master diagram, showing the general nature of these divisions together with the appropriate symbols, is shown in Figure 2.

Land form - A consideration of land form is included in the discussion of the proposed system.

Degree of Contrast Within the Profile - As will be explained in the discussion, the degree of contrast within a soil profile is a relative term insofar as engineering is concerned. It is indicated by significant differences in the engineering properties and/or problems associated with different horizons within the same profile. It is indicated in the following manner:

1. Soil profiles with significant contrast (with regard to highway construction problems - The capital letter "C" is placed behind the proper origin-type combination. Thus, in Figure 3, GMC and IgC both indicate soils whose profiles exhibit sufficient difference between their B and C-horizons to create different engineering problems for each horizon.

2. Soil profiles with little contrast - The capital letter "C" is merely omitted. In Figure 3, GM and Ig both indicate soils whose profiles exhibit little or no effective engineering differences between B and C-horizons.

Textural Nature of Profile - Estimation of Laboratory Indices - The general textural nature of the profile, and an indication of the associated laboratory test-constants, are indicated by one or two numbers. Each number represents a textural and physical class, as established by the Highway Research

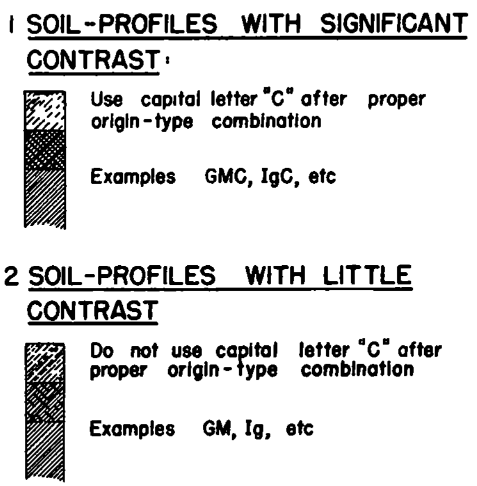

Figure 3. Existence of Profile Contrast

Board.[10] These group classifications, together with the analogous classifications incorporated in the proposed system, are shown in Table 1.

It is seen that the group-subdivisions for A-1, A-2 and A-7 have been replaced by a single number in the proposed system. This has not been done in an attempt to better reflect the characteristics of the soil, but rather to meet the requirements of simplicity and conciseness. A further consideration of this matter will be found in the discussion. The numbers indicate the nature of the profile according to the following method:

1. Soils exhibiting a significant contrast - The one or two numbers in the map-unit refer to the texture of the B-horizon (of the material in predominant topographic position or positions).
2. Soils exhibiting an insignificant contrast - The one or two numbers in the map-unit refer to the effective texture of the profile (usually the C-horizon in unconsolidated materials).

[10] See reference (15). It is to be noted that any simple, numerical system may be used in the proposed method.

As shown in Figure 4, soils qualified

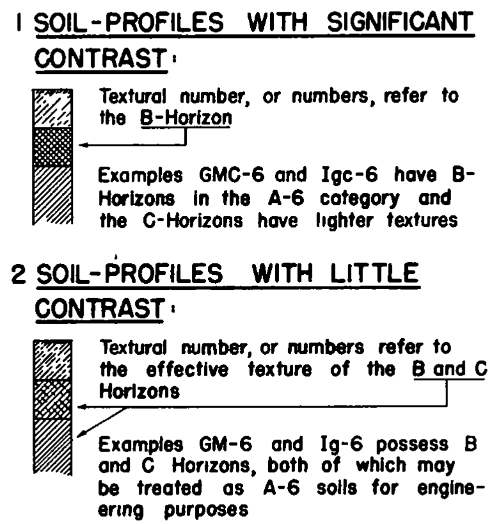

Figure 4. Indication of Profile-Texture

with a "C", indicating significant contrast, possess numbers which refer to the texture of the B-horizon where conditions are likely to be at their worst.

TABLE 1

INDICATION OF TEXTURE IN PROPOSED SYSTEM

HRB Group	HRB Group Subdivision	General Nature of Material	Analogous Number in Proposed System
A-1	A-1-a A-1-b	Stone fragments, gravel and sand	1
A-2	A-2-4 A-2-5 A-2-6 A-2-7	Silty to clayey gravel and sand	2
A-3	- -	Fine sand	3
A-4	- -	Silty	4
A-5	- -	Silty (elastic)	5
A-6	- -	Clayey	6
A-7	A-7-5 A-7-6	Clayey (elastic with high volume changes)	7

In these cases, the C-horizon can usually be safely considered as being lighter in texture. Map-units lacking the qualifying "C" possess numbers that refer to the effective texture of the B and C-horizons; these horizons being essentially similar for engineering purposes.

Drainage Condition - By interpreting the complete map-unit, the internal drainage potential, the capillary potential and the height of the ground water-table can be individually or compositely evaluated in a general way. The internal drainage characteristics can usually be estimated from the textural category and the degree of profile-development. Information concerning the capillary potential is supplied by the textural category, together with the following code for ground-water positions. The height of the ground water-table over the major portion of the area (neglecting surface intersections and their accompanying effects) is indicated by the letters shown in Table 2. Variations in the position

TABLE 2

INDICATION OF WATER-TABLE CONDITIONS

Letter	Type of ground-water condition	Position of water-table [a]
e	excellent	> 10 ft
g	good	6 to 10 ft
i	imperfect	3 to 6 ft
p	poor	1 to 3 ft
v	very poor	0 to 1 ft

[a]Below major portion of surface

of the water-table can be indicated by combining two letters such as "ip" showing a water-table position varying between 1 to 6 ft. from the major portion of the surface, depending upon position.

The only other factor of major importance in an estimation of drainage condition is the surface drainage potential. This is considered in the discussion.

Special Symbols - A few letters are used to convey special meanings in situations which depart from the normal. These letters are:

1. X - Exceptional - usually used when the parent formation, textural classes or drainage conditions are not correctly implied by the regular system.
2. R - Variable - usually used when individual factors vary in such a manner that mapping, according to the rules of the system, is not feasible.
3. d - Depression - usually used to indicate a depressed position when such information will facilitate the correct interpretation of a map-unit.
4. a, b, c, etc. - usually used at the end of identical map-units which, nevertheless, refer to areas that are different in some important respect. These letters should be used very sparingly.

Typical Map-units - In order to form each map-unit, the various letters and numbers are properly combined. The combination of the various factors is indicated in Table 3. The map-units shown refer to actual soil-areas in New Jersey. Some of these map-units are interpreted at the end of the paper.

Uniformly Intermingled Soils - Existence and Type of an Underlying Significant Strata - In some areas, two significant phases of a soil may be uniformly intermingled on an areal basis. For instance, in some very gently rolling glacial ground morainic areas, slight differences of position may create differences in soils. If both positions are equally wide-spread and also intermingled, a problem in labelling is created. The proposed system uses the diagonal bar in such cases. The above area might be mapped as GM-4i/GM-6p.

In many areas, it is extremely important to indicate the existence and type of an underlying strata which is significant with respect to engineering construction. In the system as proposed, this may be done using a fractional symbol. Thus, the symbol $\frac{GM\text{-}4i}{1b}$ denotes silty ground moraine with an immature, imperfectly drained profile overlying, at a significant depth, igneous basaltic bedrock.

TABLE 3

COMBINATION OF FACTORS TO FORM COMPLETE MAP-UNIT

Geologic Origin	+	Land form or Type	+	Profile Contrast	+	Textural Category	+	G.W.T	+	Addit. Info.	=	Final Map-Unit
G		O		-		2		g		-		GO-2g
G		M		-		4		i		-		GM-4i
G		O		-		2		v		-		GO-2v
G		MM		-		24		i		-		GMM-24i
G		M		C		6		ip		-		GMC-6ip
MM		g		C		6		ig		-		MMgC-6ig
S		h		-		4		i		-		Sh-4i
I		b		C		67		i		-		IbC-67i
G		M		-		4		i		1b		GM-4i / 1b

best-developed soils of the humid tropics [12] are noted for their great depth, essential uniformity of profile and the subordination of the effects of texture and parent material. Soils developed under the feebly-arid to sub-humid climates [13] of the Dakotas, Nebraska and Kansas are usually distinguished by appreciable surficial accumulations of organic matter, pronounced limey zones at relatively shallow depths (regardless of parent material) and relatively low degrees of B-horizon development.

DISCUSSION OF PROPOSED SYSTEM

Climate - It can safely be stated that climate has a significant effect upon the type of soil-profile which is developed in many regions, and that a majority of the soil-profiles included within such regions will display general characteristics which are both similar and typical.

The specific profile which has been considered in the presentation of this paper is one which is believed to be typical of humid-temperate to humid-cool climates. [11] Such climates exist in the New England, Mid-Atlantic, Central and North-Central States. An important characteristic of the profiles which develop in this region is a tendency toward relatively sharp differentiations between A, B and C-horizons. This differentiation is often particularly noticeable in the relative imperviousness of the B-horizon.

Profiles developed in other climates display other characteristics. The

These general similarities within climatic regions are of value in the development and use of systems such as that which has been presented. By making use of the general similarities which exist in humid-temperate to humid-cool climates, one or two numbers can serve as a key to the texture of the entire profile. In other climatic regions it may be necessary to change the significance of the textural numbers

11 Generally termed gray-brown podsolic soils and podsols by the Russian pedologists.

12 Generally termed laterites by the Russian pedologists.

13 Generally termed chernozems by the Russian pedologists.

as well as that of other factors. In such cases, however, it is believed that the changes can be made within the framework of the system. If the changes are standard in character, a relatively sketchy acquaintance with the characteristics of various regional soils will enable engineers from one region to correctly interpret the map-units of another region.

Although a knowledge of climate affords such interpretative advantages, it has not been included as an integral part of the proposed system. In most States, the soil-maps will cover areas which lie within the boundaries of a single climatic region. In cases of this sort, the climate becomes superfluous once the effect on the local region has been ascertained. It is true that in certain areas such as the Midwest soil-maps may transcend the boundaries of more than one climatic region. Even in these areas, however, the problem is still one of evaluating local effect. In other areas such as the Far West, the climatic effect is of such a nature that it becomes subordinate to the effect of parent material. In all areas, it is possible that the relation between climate and natural water-conditions is more important than the relation between climate and general profile-characteristics. Therefore, although the overall climatic effects are not to be disregarded, the proposed system neglects them in favor of specific factors which seem to be of more value to the user.

Origin and Type of Parent Formation - Land Form - The importance of these factors to the soils and construction engineer has been described in many professional papers of the past decade.[14] The following discussion will consider them only with regard to their use and interpretation in the proposed mapping system.

The initial letters of origin, combined with the secondary letters of type, immediately describe the fundamental characteristics of the parent formation in a manner which conforms to widely accepted geologic nomenclature. In addition, however, these symbols help to form in the user's mind a mental picture of important environmental conditions which exist in the mapped area. For example, the combination GMM mapped over an area indicates that the soil is unconsolidated, glacial in origin and deposited as a marginal moraine with an irregularly hummocky surface, a hetergenous composition and a probable great depth to bedrock. In general, most of the combinations shown in Figure 2 under the non-residual heading perform a similar function. Such units as GK (glacial kame), WD (windblown dune), AR (recent alluvium) and GO (glacial outwash) each give information concerning the land form, origin and general character of the material.

The same amount of information is not supplied by all of the non-residual combinations shown. Such categories as GS (miscellaneous stratified drift), AM (undifferentiated alluvial mantles) and WL (windblown loess) do not usually give information concerning both the land form environment and the general nature of the material. This calls attention to an important point concerning the non-residual land form categories listed in Figure 1. Most of these combinations are included because they:

1. Possess a land form which is usually easily identifiable both in the field and on the airphotos, and/or
2. Possess characteristics which are of importance to highway engineering.

Classifications such as GS, AM, etc. are not usually characterized by easily distinguishable land forms. They are instead, miscellaneous or general categories. They are included so that the maker and user of the map need learn only a relatively few important land forms and can place doubtful areas in a category without spending the time which might be necessary in order to formulate new combinations or precisely classify the doubtful area. The unit GS is a good example since it covers those deposits of stratified glacial drift

[14] See references (*5*), (*6*), (*11*), (*12*), (*13*) and (*14*).

which are often not characterized by any particular type of land form.

The combinations shown in Figure 2 under the residual heading do not supply the same information as the non-residual classification. For instance, the combination Sh indicates that the area in question has a residual soil-mantle, derived from bedded shale at a probable shallow depth. This information is extremely important to the engineer. However, other questions concerning the orientation and thickness of the beds and hardness of the rock are not answered. At least, however, these factors are indicated as being primary considerations in any discussions which may follow.

An important point about Figure 2 concerns the ease with which the various combinations can be remembered, or reconstructed, by virtue of their association with the first or second letter of the applicable word. Another advantage of the chart is its wide coverage, an estimated 90 percent of the bedrocks and unconsolidated types which would normally be encountered in ordinary engineering construction.

The labelling of residual soil areas which are developed upon interstratified formations constitutes a slightly different problem. Experience in New Jersey has indicated that interstratification may be considered normal for deposits of sedimentary origin, but that one material usually displays a definite predominance. In these cases, the developed soil-profiles have reflected this predominance to such an extent that the areas have been mapped and considered as being composed of a single material. One example is found in the large areas of interstratified silty shale and fine sandstone which cover west-central New Jersey. In these areas, the effect of the minor sandstone outcrops is negligible, the soils are essentially silty and the areas can be mapped under the combination Sh-4i. If the area to be mapped has interstratification to a significant degree, and the level of generalization is such that individual strata cannot be mapped separately, a combined symbol can be utilized. Thus, significantly interstratified beds of sandstone and shale may be mapped under the combination Ssh.

There are additional special problems encountered in the mapping of residual areas. These are discussed in connection with the special symbols.

Degree of Contrast Within the Profile - To an engineer, the contrast possessed by a soil-profile depends upon differences in the engineering properties of horizons within the profile. If the various horizons are sufficiently different to create separate engineering problems in the field, the profile can be considered as one having significant contrast. In the proposed system, the presence of significant contrast is indicated by a "C" after the proper origin-type combination. If contrast is unimportant, the "C" is omitted. It will be noted that the exact nature and probable effect of the contrast is relegated to the important descriptive bulletin which should accompany the soil-map.

The decision regarding the presence or absence of a significant contrast is left to the engineer or engineers who are responsible for mapping. In those instances when agricultural and pedological information are utilized as mapping or interpretative aids, it should be thoroughly understood that the engineering concept of profile-contrast may not necessarily have the same meaning as the pedological concept of profile-maturity. A pedologically mature profile is one which has progressed to a state closely resembling that which might ultimately be expected to develop under the existing climatic conditions.

From the viewpoint of the highway engineer, a pedologically mature profile need not show significant contrast. An excellent example of the distinction exists in the coastal plain of New Jersey. Here the Lakewood series has developed pedologically mature profiles upon a parent material composed of quartz sand with very few fines. To the engineer, the Lakewood profiles do not show important contrast, since the engineering properties and the resulting field behavior of the various horizons are practically identical. Thus, the Lakewood series, in a practical sense, is one horizon throughout. Certain members of the Sassafras series, however, are developed upon parent material composed of quartz sand containing considerable silt and some clay. These Sassafras soils are pedologically immature, since their horizons have not progressed sufficiently far toward their ultimate development. To the engineer, however, these members show contrast, since enough silt and clay have accumulated in the B-horizon to create different properties with respect to construction operations.

Textural Nature of the Profile - As stated previously, the general textural nature of the profile is indicated by one or two numbers, each number representing a general textural category as defined by the Highway Research Board Classification of 1946. Tow numbers are allowed, because extensive sampling in New Jersey has indicated that many soils can best be defined by a range of textures rather than by a single texture. To illustrate this point, Table 4 shows the classification for

TABLE 4

CLASSIFICATION OF SOME MORAINE SOILS

Geologic Origin - glacial

Geologic Designation - marginal moraines

Geologic Description a belt of irregularly hummocky accumulations of clay, silt, sand, gravel, and boulders in a confused mixture

Counties - Union and Middlesex, New Jersey

Map-Unit - GMM-24i

Sample No.	B-Horizon HRB Class	B-Horizon Group Index	C-Horizon HRB Class	C-Horizon Group Index
306	A-1-b	0	A-2-4	0
2013	A-2-4	0	A-2-4	0
2014	A-4	3	A-4	4
2027	A-4	5	A-4	1
2028	A-4	4	A-4	1
2030	A-4	3	A-2-4	0
2034 [a]	A-6	5	A-4	5
1805	A-4	5	A-4	5
1806	A-4	2	not taken	-
1807	A-4	7	not taken	-
1812	A-4	5	A-4	6
1824	A-4	4	A-4	3
1828	A-4	2	A-4	0
1834	A-4	5	A-1-a	0
1844	A-2-4	0	A-2-4	0
1847	A-4	5	A-2-4	0
1849	A-4	5	A-4	0
1831 [a]	A-7-6	7	A-6	7

[a] Blind depressions

gently undulating to undulating surface. Since the described system, as presented, refers only to specific climatic conditions, the profile may be expected to consist of three horizons. However, since the symbol is not qualified by the letter "C", the profile can be considered, for engineering purposes, to consist of essentially a single horizon. In this case, the textural number refers to both B and C-horizons and indicates that these horizons belong in the HRB 2-group. The 2-group of soils are silty to clayey sands and have a wide range of associated test constants. This group may be expected to provide a fair to good subgrade support, and a probable good source of borrow. The absence of a fractional symbol indicates that bedrock, or any other significant strata, need not be considered during ordinary highway construction. Because the land form has a gently undulating to undulating surface, cuts and fills can probably be kept to a minimum. The letter "g" implies a ground water-table which is usually 6 to 10 ft. below the ground surface. The texture, lack of contrast, etc. eliminate internal drainage and capillarity as important considerations, leaving only surface drainage structures as possible major requirements.

The map-unit GO-2v, not shown in Figure 5, indicates similar material with, however, a very poorly drained condition at times during the year. Since the textural nature of the B and C-horizons is silty to clayey sands, it is probable that the poor drainage is not the result of either poor internal percolation or excessive capillary moisture. The letter "v" indicates that the ground water-table is high, probably because the area is a depression. If so, surface drainage conditions are adverse.[15] Depressions may be expected to accumulate organic material on the surface. Highway alignments should avoid such areas. If highway construction must be undertaken, the organic mat will probably require removal, compacted fills will be necessary, cross-drainage will be required and special techniques used throughout construction.

The map-unit GM-4i indicates that the soil is derived from unassorted ground till. The formational history of such deposits usually dictates that the area will be more or less rolling. Since there is no fractional symbol, it is probable that the till is fairly thick, tending to mask the original relief, and indicating that an underlying formation need not be considered in the construction of highways. Since the qualifying "C" is absent, the profile lacks contrast and may be considered as a single horizon throughout. The textural number, 4, indicates that the horizon is generally silty throughout. This textural group provides questionable subgrade support. The land form indicates that shallow cuts and fills may be expected with some frequency. Alignment will probably not be difficult. The letter "i", indicating a ground water-table existing at depths of 3 to 6 ft., together with the textural category, calls attention to the probability of adverse internal, capillary and ground-water conditions. The possibility of frost action may also be a factor. In general, the area may be considered as one to be avoided if possible. If construction must be undertaken, particular attention should be accorded to drainage and subgrade conditions.

The map-unit GMC-6ip, not shown in Figure 5, mapped over large areas, indicates that the soil is derived from old glacial morainic till. Since the area is large and no fractional symbols are indicated, it is probable that the drift is deep, and an underlying formation need not be considered. The land form will probably be gently rolling, with advanced erosion in some areas. Since the profile shows significant contrast, it is probable that different construction problems will be encountered on different horizons. The B-horizon has a clayey texture, probably moderately heavy, and the C-horizon is somewhat lighter, say an A-4 to an A-6, with a low index. Drainage facilities will require careful attention,

[15] The area could be mapped with a "d", i. e. GO-2vd, directly indicating a depressed position.

since the ground water-table varies between - 1 to 6 ft. from the surface (probably dependent upon position), contrast is high, and texture is not conducive to good internal drainage or low capillarity. Raised grade lines may be necessary in the lower areas. Borrow will probably have to be imported. Deep cuts need not be frequent.

The map-unit MMgC-26ig, not shown in Figure 5, indicates a residual soil derived from gneissic bedrock. The land form may be expected to be quite rough. The soil shows significant contrast, indicating that different problems may be expected when different horizons are encountered. The B-horizon shows an apparent wide variation in texture, ranging from a clayey sand to a clay. The C-horizon will probably be lighter, composed largely of clayey sand, with numerous rock fragments as bedrock is approached. The position of the ground water-table, combined with reasonably frequent sandy textures and probable steep slopes, all indicate fair surface drainage and internal drainage with probable low capillarity in many areas. The high contrast tends to discount these factors. Therefore, drainage should be carefully investigated. Cuts into bedrock and fills may be expected to occur with some frequency. Alignments may be difficult. The soil may be expected to provide a fair to good support in the C-horizon.

The above interpretations are typical and indicate that the proposed system, if properly used, provides a useful aid to the engineer who must consider soils on an areal basis. In summary, it is desired to enumerate a few less obvious attributes of the proposed system which are of special significance in highway engineering:

1. Because of a simple yet informative character, the system is of value to the higher levels of planning and supervision who do not always have the opportunity to evaluate soil conditions, either from field observations or from personal study.

2. Because of a uniform character, similar soils are identified by similar map-units. Thus, engineers from different areas can rapidly and accurately evaluate the general characteristics of soils beyond their own domains. This is of great value in disseminating constructional techniques. In addition, it serves as a point of departure for investigating unequal performances on similar soils.

3. Because of a general character, it is believed that the system can be applied to other climatic regions with different type profiles. Even though the meaning of numbers and letters will be changed, the change may occur within the framework of the system.

4. Lastly, it is couched in engineering terms and designed for practical use. While retaining most of the elements upon which agricultural identifications are based, it tends to decrease the importance of learning, and remembering, innumerable agronomic names, their associated properties, and their engineering significance.

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