SIGNIFICANCE OF THE SOIL SURVEY REPORT IN THE SELECTION AND PRELIMINARY ASSESSMENT OF SITES FOR AIRPLANE LANDING STRIPS[1]

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Most of the writer's time was spent, during 1943, 1944 and 1945 while on leave of absence from the University of California, with the Military Geology Unit of the U. S. Geological Survey, in preparing soils information for the Office of the Chief Engineer in Washington and for the Chief Engineer, Southwest Pacific Area, in that theater The soils information was used, together with much other information of a geological, hydrological and general engineering character, in strategical and operational engineering reports. Advance knowledge of soil conditions before, during and after combat was, of course, of much importance in a variety of ways, including utilization for troop and equipment movement and in road and airfield construction. Wherever they existed, the value of soil survey reports for this kind of intelligence was conspicuous. They were of great help also in airplane photo interpretations.

It is the writer's belief that engineers who use soil as a construction material will find, in soil survey reports, much of value in the preliminary assessment of areas for many construction operations. It is for this reason that comparisons were made between conditions predicted from independent interpretation of soil survey reports and actual engineering experience, for five airplane landing strips in California.

The use of soil as a construction material was very greatly extended during the years 1939 to 1945, primarily as the result of the acute military need for roads and airfields. The need, commonly, was so urgent that site selections had to be made hurriedly. Accordingly, in territory occupied by ourselves and Allies, there were instances in which there was little opportunity for deliberate study of all available published material dealing with the areas under consideration.

During military operations overseas, particularly in the Asiatic-Pacific Theater, the problem was largely one of planning the use of unimproved, or but slightly improved, ground in enemy-occupied territory prior to its invasion. Any existing reports by geologists and soil scientists were found to be of much value in assessing ground conditions. In a large number of instances the invaded territory was entirely unexplored on the ground in advance

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of our landings. Selection of construction sites in such cases was mainly dependent upon aerial photographs. A preliminary report of the methods used in terrain analysis by intelligence units working in Washington and overseas has recently been published by the Military Geology Unit of the United States Geological Survey *(18)*[3].

Sources of information helpful to the engineer in the actual selection of airfield sites and roadway routes will obviously differ from place to place and may be non-existent. In the absence of reports based on more or less detailed studies on the ground, stereopairs of recent, large-scale, vertical aerial photographs are invaluable and even though actual ground studies have been made, such photographs provide useful supplementary information for estimates of conditions affecting many kinds of engineering operations. Where, however, ground conditions have been explored, particularly in a great number of agricultural regions in this country, probably the most valuable sources for the construction engineer who must make extensive use of the soil as a subgrade or base course material, are those provided by modern soil survey reports as developed by the United States Department of Agriculture and the State agricultural experiment stations.

It is unnecessary to point out to students in the field of soil science that soil surveys mark the first step in any kind of comprehensive investigation on soils of a given area, although this fact may not be so clear to many engineers. There are many examples of the way in which engineers have put soil survey data and methods to use (see, for example, reference 2, and also *11*, p. 116) but it appears that soil scientists and soil engineers have not always realized the full extent of the usefulness of these reports. As a matter of fact, the general information sought by the engineer in his choice of an airfield site agrees surprisingly closely with that desired by the prospective farmer and others whose interest in land areas and their soils is primarily due to agriculture. The soil survey report is, of course, designed to include information useful to the farmer and the agricultural community. Apart from the soil maps and soil profile descriptions contained in soil survey reports, therefore, the treatment which the reports give to such matters as topography, ground surface conditions, obstructions to movement on the ground, natural vegetation, its clearing requirements and value for construction, size of farms, land utilization, farm practice and cropping systems, meteorological data, drainage, flood danger, irrigation, water supply and quality, nearness to towns, roads and railroads, electric power and so forth, is of the greatest value in the preliminary selection of airfield sites.

The detailed discussions and maps, concerning soil types, their profile characteristics and their areal extent, may be expected to provide information, as they actually do, which will considerably extend the engineer's knowledge of the ground as a prospective site for construction and facilitate his successful advance planning.

It is of particular interest to the soil physicist to consider the fact that highway and airfield construction engineers often seek to create in earth structures many conditions which the farmer dislikes in soils used for crop production. Whereas the engineer desires high apparent densities, low porosities and high bearing strength, the creation of those conditions in agricultural soils is avoided under good agricultural practice since, in general, they are associated with an undesirable "structural" state, poor tilth, low permeability to water and obstruction to root growth. Although their objectives diverge, however, agricultural soil research workers and soil engineers commonly find themselves confronted with problems requiring the same or similar methods of attack and solution so that the efforts of both groups may be expected to provide mutual stimulation in research.

An attempt is made in this paper to interpret, for the use of the engineer whose construction material is soil, ex-

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[3] Italicized figures in parentheses refer to the list of references at the end of paper.

isting soils information contained in a few soil survey reports which embrace areas later chosen for airfield sites. Following the interpretations there is included a discussion of their correctness, made in the light of construction experience and laboratory examinations undertaken, with the soil types concerned, by the Materials and Testing Section, U. S. Engineer Office, Sacramento, California. It is hoped in this way to bring to the construction engineer a realization of the value of the soil survey report in the preliminary assessment of soil conditions at proposed sites for airplane landing strips.

PROCEDURE

It was considered necessary that the soils of the particular localities chosen for examination fulfill these requirements:

(a) they must have been included in soil surveys (made according to the methods used by the Division of Soil Survey, U. S. Department of Agriculture) for which maps and descriptive reports exist, preferably in the published form,

(b) they must be sufficiently representative of a range of differences in soil properties that they will provide a reasonably significant sample for consideration,

(c) they must have been used as the actual materials of subgrade construction for airplane runways,

(d) they must have been subjected to quantative physical examination and testing in an engineering laboratory for the purpose of guiding construction design.

SOILS AND CONSTRUCTION SITES CONSIDERED

Five localities were selected within, or immediately adjacent to, the Sacramento and San Joaquin Valleys of California. The localities and airstrip names are listed, from north to south, in Table 1, in which reference also is made to the soils of each area and the soil survey report concerned. The most northern field, at Orland, lies about 190 miles northwest of the most southern, at Merced. The position of each strip with respect to land boundaries (Mount Diablo base line and meridian) soil types and topography is shown in the maps and diagrams of Figure 1, the data for which were obtained from the soil survey reports *(6, 7, 10, 12, 13)* Geological Survey topographical sheets *(17)* and from airfield location and runway dimension maps as prepared by the U. S. Engineer Office, Sacramento.

The characteristics and agricultural utilization of the soil types at the five locations upon which airplane runways have been constructed, are tabulated in Table 2. In the table, the soil type names, soil utilization, parent material, relief, surface drainage, and average depth range of horizons are all summaries directly dependent upon the reports of soil surveys made several years before construction of the runways was undertaken. A key to the soil series of California *(16)* was also consulted. The summaries refer, for each area, to the soil type as a whole -- unless local segregations were actually made in the report -- that is to say, the descriptions generally are not based upon examination of the soils only as they occur in the position of the runways before construction but upon the types as they occur in the entire area covered by soil survey.

It may be pointed out that "soil type" names, as used by soil surveyors when making an agricultural soil survey, are a combination of a "soil series" name (e.g. in the case of soil 11, Tables 2, 3 and 4, the series name is 'Elder'; soil 71 has the series name 'Stockton') and a "textural class" name (soils 11 and 71 have respectively, the textural class names 'gravelly loam' and 'clay'). Much information concerning the soil may be obtained from the series name. A soil series comprises a group of soils, all members of which are similar with respect to the characteristics of the undisturbed soil profile, with a single exception of the texture of the surface soil. Members of the same soil series have a similar geologic origin and also have similar external characteristics and environmental conditions such as relief, drainage,

TABLE 1. LANDING STRIP NAMES, LOCATIONS AND SOIL TYPE NUMBERS

Name	Location	Soil Survey Area	Soil Type Number (See Table 2 and Figure 1)
Orland Auxiliary Field A-1	3 miles ESE of Orland	Sacramento Valley Reconnoissance (10)	11, 12
Fairflied-Suisun Airport (NE-SW Runway No. 2)	7 miles ENE of Fairfield	Suisun Area (6)	21, 22, 31, 41, 51
Kingsbury Auxiliary Field A-1	5½ miles SW of Lodi	Lodi Area (7)	61
Stockton Field, Mat "B"	3½ miles SSE of Stockton	Lower San Joaquin Valley Reconnoissance (12) and Stockton Area (13)	71
Merced Army Airfield (NW-SE Runway)	6½ miles NW of Merced	Lower San Joaquin Valley Reconnoissance (12)	81, 91

vegetative cover, kind of climate, and others. The textural class name, as used in the soil type name, refers to texture, that is fineness of grain, or particle size distribution, in the surface soil only. Knowledge of the texture, degree of compaction, presence or absence of hardpan and of rock, lithology of the parent material and many other physical, as well as some chemical, qualities of the subsoil and/or deeper parts of the soil profile, can be gained from the soil series name, which is described with regard to these properties, in the soil survey report.

METHODS OF INTERPRETATION

The three columns of Table 2, under the heading, "Engineering Classification", contain interpretations of the soil survey descriptions into terms and abbreviation symbols adopted by engineers and those in the field of soil mechanics *(19,21)*. In the interpretation, reference was made, where possible, to mechanical analyses published in the soil survey reports for the different types and their horizons. In addition, descriptions and size distribution curves accompanying the Corps of Engineers and Public Roads Administration Symbols *(21, 19)* were given consideration.

Entries made in the columns under the general heading, "Estimated Soil Properties", depend partly upon other considerations. The estimates of volume changes (expansion and shrinkage) and permeability

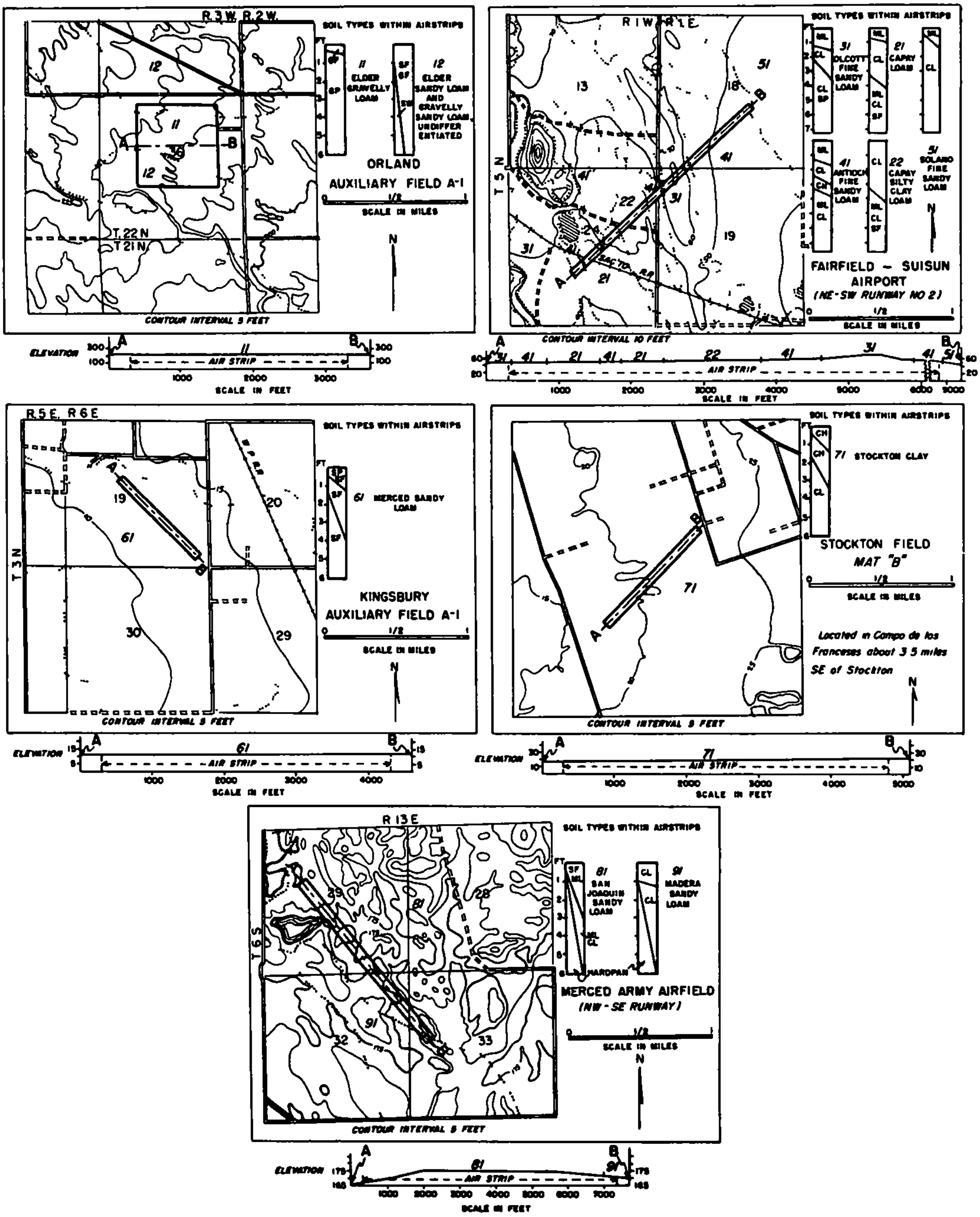

Figure 1. Positions of finished landing strips in relation to soil types and local topography. Soil boundaries are shown by dotted lines, contours by unbroken lines. Symbols used in soil profile diagrams are defined in Table 2, footnote 1. Consult Table 1 for sources of soil survey information.

TABLE 2. NAMES, UTILIZATION, CHARACTERISTICS AND ESTIMATED ENGINEERING PROPERTIES OF SOILS UPON WHICH LANDING STRIPS HAVE BEEN CONSTRUCTED

Locality	No.	Soil Type Name and Utilization	Parent Material	Condition in Undisturbed State				Equivalent Engineering Classification			Estimated Soil Properties:			
											Before Modification by Construction Operations			
				Relief	Surface Drainage	Average Depth Range of Horizon, Inches	Texture Class Name	Engineering Name	Engineering Group Symbol[1]	Public Roads Administration Class Symbol[2]	Expansion and Shrinkage	Relative Perme-ability	Average Range in: Plastic Limit Percent	Plasticity Index Percent
Orland Field	11.	**Elder** gravelly loam (grazing)	Alluvial fans of unconsolidated sediments from metamorphic rocks	Irregular, low relief with small intermittent streamways	Fair to poor	0-5	Gravelly loam	Gravel with fines	GF	A-2	Slight to none	High	Very slightly plastic to non-plastic	
						5-72+	Gravelly loam, Gravelly sand.	Poorly graded gravel; sand mixture	GP	A-3		Very High		
	12.	Elder Sandy loam and gravelly sandy loam undifferentiated (grazing)	Alluvial fans of unconsolidated sediments from metamorphic rocks	Irregular, low relief with small intermittent streamways	Fair to Poor	0-18	Sandy loam; gravelly sandy loam	Chiefly sand with fines	SF some GF	A-2	Slight to none	High	Very slightly plastic to non-plastic	
						18-72+	Gravelly sandy loam	Gravelly sand	SW	A-3		High		
Fairfield-Suisun Airport	21.	Capay loam (grain; grazing; some fruit trees)	Mixed, unconsolidated sediments of low plains	Low relief	Fair to poor	0-11	Loam	Silty and Clayey fine sand	ML	A-4	Medium	Low	15<25	5<15
						11-45	Clay loam	Silty and sandy clays of medium plasticity	CL	A-6	Medium	Low	15<25	10<20
						45-72+	See footnote 3	See footnote 3	ML, CL, some SF	A-4, A-6, some A-2	----	Medium to low	15<25	<20
	22.	Capay silty clay loam (grazing; some grain)	Mixed, unconsolidated sediments of low plains	Low relief	Very poor	0-45	Silty clay loam	Plastic inorganic silty clay	CL	A-7	High	Very low	15<25	10<25
						45-72+	See footnote 3	See footnote 3	ML, CL, some SF	A-4, A-6, some A-2	----	Medium to low	15<25	<20
	31.	Olcott fine sandy loam (grazing; grain; some fruit)	Mixed, commonly unconsolidated or weakly consolidated sediments of low, dissected terraces	Low hills or slightly raised plains	Good	0-17	Fine sandy loam	Clayey fine sand	ML	A-4	Medium	Low	18<25	<10
						17-33	Sandy clay; clay	Plastic sandy clay, or clay	CL	A-6, A-7	Medium	Very low	20<28	15<25
						33-72+	Semi-consolidated clay and sand	Interbedded, s semi-consolidated clay and sand	CL, SP Interbedded	A-6, A-3	----	Medium to low	15<25	<15
	41.	Antioch fine sandy loam (grazing; grain)	Mixed, unconsolidated sediments of old alluvial fans and terraces	Flat to gently undulating or sloping	Fair to poor	0-18	Fine sandy loam	Clayey fine sand	ML	A-4, A-6	Medium	Low	12<20	5<15
						18-33	Clay; silty clay	Plastic clay	CL, CH	A-7	High	Very low	16<24	15<25
						33-43		Silty, sandy clay	CL	A-6	Medium	Low	15<22	5<20
						43-72+	Fine sandy loam	Clayey sand to sandy clay	ML, CL	A-4, A-6	Medium	Low	15<25	<20
	51.	Solano fine sandy loam (grazing)	Mixed, unconsolidated sediments of old alluvial fans and terraces	Hummocks and depressions form low micro-relief	Fair to poor	0-12	Fine sandy loam	Clayey fine sand	ML	A-4	Medium	Low	12<18	<10
						12-72+	Sandy clay; clay	Sandy clay and clay	CL	A-4, A-6	High	Low	16<20	10<25
Kingsbury	61.	Merced sandy loam[4] (grazing; some grain)	Mixed, unconsolidated sediments of valley plain	Nearly flat with few minor irregularities	Fair to poor	0-11	Sandy loam	poorly graded sand and sand with fines	SP, SF	A-3, A-2	Low	High	Very slightly plastic to non plastic	
						11-33	Sandy loam; loam	Sands with fines, compact	SF	A-2	Low	Low		
						33-72+	Sandy loam	Sand with fines	SF	A-2	Low	High		
Stockton Field	71.	Stockton clay (grain; some fruit; grazing)	Largely basic sediments of valley plain (profile has calcareous hardpan)	Flat	Very poor	0-11	Clay	Highly plastic clay	CH	A-7	Very High	Very Low	16<24	20<35
						11-30	Clay	Highly plastic clay	CH	A-7	Very High	Very Low	20<30	25<40
						30-72+	Clay; sandy clay	Silty and sandy clay	CL	A-6, A-7	High	Low	15<25	10<20
Merced	81.	San Joaquin sandy loam (grain; grazing; some fruit where irrigated)	Acid-igneous sediments of old terraces (profile has non-calcareous hardpan)	Low relief, commonly with many mounds and depressions	Fair	0-20	Sandy loam	Fairly well graded sand: clay mixtures	SF, ML	A-2, A-4	Low	High	10<18	<8
						20-38	Sandy clay; clay	Sandy clay and clay	ML, CL	A-4, A-6	Medium	Low	15<25	5<15
						38-72+	(Hardpan)	Hardpan	- -	- - -	- - -	Very low	- - -	- - -
	91.	Madera sandy loam (grain; grazing; some fruit and truck crops where irrigated)	Acid-igneous sediments of old terraces (profile has hardpan)	Low relief on level to sloping surface	Fair to good	0-8	Sandy loam	Clayey sand	CL	A-4	Low	High	10<18	<5
						8-42	Sandy clay loam	Silty and clayey fine sand	CL	A-4	Medium	Medium	12<20	5<15
						42-72+	(Hardpan)	Hardpan	- -	- - -	- - -	Very low	- - -	- - -

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[1] *Corps of Engineers Group Symbols:* These symbols are used in the Corps of Engineers Soil Classification Table published in War Department Technical Manual TM 5-255 (15 April 1944) Table V, pages 84, 85. The letters have the following meanings: G=gravel; S=sand; F=fines (material <0.1 mm.); M=very fine sand, silt; C=clay; L=low to medium compressibility; H=high compressibility; P=poorly graded; W=well-graded (i.e. a wide range of particle size distribution.)

[2] *Public Roads Administration Class Symbols:* These symbols are described in numerous publications of the U. S. Public Roads Administration (e.g. Principles of Highway Construction, June, 1943). See also C. A. Hogentogler *(9)* and others. The approximate equivalence of the Corps of Engineers and Public Roads Administration symbols may be obtained from the War Department Manual TM 5-255.

[3] Soil Material estimated to show wide difference in character in this depth range.

[4] May contain alkali salts.

depend primarily upon texture descriptions and a few specific discussions in the survey reports, combined with some knowledge of the properties of the soil clays, and experience in field and laboratory. In some instances laboratory experiments had been conducted at an earlier time with samples of the actual soil types concerned, but not from these localities and entirely unconnected with landing strip construction. It is believed that any experienced worker in the field of soil mechanics, who is fully familiar with soil survey methods, would, after a careful study of the soil survey reports, arrive at essentially the same estimates of these properties as those given in Table 2.

Soil engineers regard the arbitrary measurements of plasticity constants, viz. plastic limit (rolling-out limit) liquid limit, plasticity index and impact number-moisture content curves of manipulated soil, as indicators of soil behavior under stress, and of the moisture content at which marked changes in behavior take place. These values are, therefore, given a certain amount of critical significance in engineering design. For these reasons, although no plasticity determinations had been made for these particular soils, it was considered worthwhile to discover the extent to which useful approximations to the rolling-out limit and the plasticity index could be made from the soil survey data. The estimates, in Table 2, of the ranges in plasticity values are the result of the translation of the soil texture terms as they were used at the time of the soil surveys, into the numerical and graphical data of mechanical analyses *(8, 19, 4)* and thence, by means of published correlation data *(3, 4, 9, 14, 15, 19)* into plastic limits and plasticity indices. The technical manual for aviation engineers *(21)* was also used in the plasticity estimates. The latitude, with respect to particle size distribution, which is permitted in soil texture-class names and in engineering texture-class symbols, the limited amount of exact knowledge which is possessed concerning the physics and physical chemistry of plasticity phenomena in soils, and the arbitrary nature of the measurements, combine to produce complicated and imperfect correlations between soil series and soil texture names, and plasticity 'constants'. Since, also soil types as mapped necessarily include a range of differences in profile properties, it is only possible to estimate plasticity values to within broad ranges. It is such ranges which are included in Table 2. It is not suggested that these, or any other estimates given in this paper, can replace detailed, direct measurements for the soils concerned, which must necessarily follow site selection and precede actual design.

The California bearing ratio (CBR) is used to determine the quality of the base course and subgrade materials. It is also a most important means of evaluating the structural qualities of the soils at the site, the need for replacement by, or mixing with, gravel or crushed rock ('aggregate' material) and the thickness and other design features of the base course. The measurement of the ratio is made on the undisturbed soil, and also on soil material previously compacted to its maximum density and then saturated with water. Apparent density tests of field soil and compacted specimens in the laboratory are made concurrently with CBR tests. In addition to a background of experience in actual performance of the test, estimates of the CBR depend upon the correct interpretation of soil texture-class names into engineering class symbols and the correctness of the numerical values for the bearing ratio percentages which the soil mechanics workers with the Corps of Engineers have assigned to those symbols *(21,* Table V). Estimates of CBR were made for all soil types, by soil horizons, but have not been included in Tables 2 and 4. The estimates are, however, discussed later. If desired, soil apparent densities ('unit' densities) at 'optimum' compaction and corresponding void ratios can be estimated by reference to the same source, intermediate values for the latter being obtainable by nomograms *(5)* or by calculation.

TABLE 3 ESTIMATED CONSTRUCTION PROBLEMS ON SOIL TYPES

Soil No	Name	General Soil Conditions and Their Improvement
Orland Auxiliary Field, A-1		
11	Elder gravelly loam	Low lying areas may cause local drainage problems Hummocks and low ridges need levelling Compaction likely to be more successful with loaded hauling equipment and tractors than with sheepsfoot roller
12	Elder sandy loam, and gravelly sandy loam, undifferentiated	
Fairfield-Suisun Airport		
21	Capay loam	Drainage, and elevation of grade line necessary Clayey, plastic subsoil interferes with drainage and forms inferior subgrade Insulation of base course against upward water movement is desirable
22	Capay silty clay	Natural drainage of this soil type is poor and soil quality for subgrade use is distinctly inferior Soil requires drainage, grade line should be raised, and stripping and replacement with suitable aggregate are desirable for heavy loading
31	Olcott fine sandy loam	Surface drainage is fair to good but low permeability of plastic clay horizons seriously restricts internal drainage May require levelling followed by removal of the clay horizon where exposed in cut
41	Antioch fine sandy loam	Fine-textured, clay-rich horizon in second and third foot commonly causes a boggy, muddy condition during rainy season Adequate side drainage of strip is essential, stripping and replacement of upper 3 feet may be necessary Grade line elevation is desirable
51	Solano fine sandy loam	Drainage conditions are very poor and problems of improvement for construction are similar to those given for the Antioch fine sandy loam
Kingsbury Auxiliary Field, A-1		
61	Merced Sandy loam	Land is low-lying and requires drainage, water penetration is retarded by compact horizon at depth of about one foot from surface, which may cause local ponding of water Grade elevation is desirable High sand content may interfere with efficiency of sheepsfoot roller
Stockton Field, Mat "B"		
71	Stockton clay	The low-lying, poorly drained and flat position occupied by this soil type makes it an undesirable one for construction Very little drainage is possible owing to low elevation Compaction of subgrade, essential in order to improve bearing ratio, would probably be best accomplished at end of rainy season Grade line requires raising A good quality aggregate should be used in the construction of base course to provide insulation against upward water movement during period of high water table level
Merced Army Airfield		
81	San Joaquin sandy loam	Levelling requirements are light, except locally owing possibly to micro-relief which may be conspicuous on the San Joaquin sandy loam Clayey subsoil layer should be stripped, particularly where intersected by grade line Hardpan, found at depth of 3 to 5 feet, in places deeper, seriously interferes with free underdrainage during wet season, and may require blasting for ditches and before grading
91	Madera sandy loam	

Table 3, based on series and type descriptions in the soil survey reports, states what construction problems may be expected at each of the airfield sites. The statements are the result of interpretations of ground conditions as influenced by topography and soil profile characteristics.

EXAMINATION OF RESULTS

Whereas standard engineering soil tests made according to accepted A.S.T.N. and A.A.S.H.O. methods in the U. S. Engineer Sacramento District Laboratory, and construction experience gained by engineers in the field, provide the criteria of reliability for the estimates in Tables 2 and 3, Table 4 has been prepared as an aid to comparison between these estimates (part A) and actual determinations (part B) and as a basis for criticism of the interpretations.

Examination of Table 4 leads to these conclusions:

(a) Soil profile descriptions with respect to depth, thickness and textural characteristics of horizons as contained in the soil survey reports were, on the whole, confirmed by the samplings later made in greater numbers by the engineers during their field collection of test samples. Those differences which were observed can probably be attributed to soil heterogeneity within the type which, owing to scale limitations, could not be shown on the published soil survey maps. Where unmapped soil differences do occur it is evident that the estimated soil properties may be in disagreement with those actually discovered by the engineering study. Some such instances were found in the present study.

Engineering practice differs in the use of names descriptive of the 'grain size' properties of soil material. The engineers' and the soil surveyors' terminologies are not always so similar as might be suggested by comparing the names in the soil type column (part A) and the engineering name column (part B) of Table 4.

(b) Close agreement was obtained between estimates of classification symbols and their determination based on engineering laboratory measurements.

(c) Comparisons of estimated and determined numerical ranges in plastic limits and plasticity indices, respectively, show good agreement.

(d) Estimated values of bearing ratios at optimum compaction were, except for the soils of the Stockton and Kinsbury landing strips, much lower than those obtained in the engineering laboratory.

The discrepancies may be explained in part by the fact that lower bearing ratio magnitudes have been assigned to the various engineer soil categories in the technical manual of the aviation engineers *(21)* than have been observed to prevail in many of the medium and coarser grained California soils, and also to the use of a slight modification in procedure in the more recent bearing ratio tests. It is most significant, however, that soils that appeared to be the most suitable subgrade materials as judged by the estimated CBR values were actually found to be the most suitable materials for this use when considered on the basis of values determined in the engineering laboratory.

(e) The conditions and predicted construction problems, arranged in Table 3 by soil types and airfields, were well supported by experience at the time of runway construction in all cases but one. An unpredicted condition was found at the Merced runway where on the soil survey map only one soil type, San Joaquin sandy loam, was shown. In places a complex of two types was actually found to exist, consisting of the San Joaquin sandy loam in close association with included, small bodies of a clay-rich soil type occupying shallow depressions. The surface of this included soil that had to be removed during construction owing to its low bearing ratio. Because of their small size the areas of the depression type could not have been shown on the reconnaissance soil map.

SUMMARY AND CONCLUSIONS

In order to determine the value of soil survey reports in the selection and pre-

TABLE 4 COMPARISON OF ESTIMATED AND DETERMINED ENGINEERING PROPERTIES OF SOILS AT LANDING STRIP SITES

Locality	Part A. Estimated Values								Part B- Values Determined in U S. E. D. Laboratory[3]						
							Average Range in						Average Range in		
	No	Soil Type Name	Average Depth Range of Horizon, Inches	Engineering Name	Engineering Group Symbol[1]	Public Roads Administration Class Symbol[2]	Plasticity Index Percent	Plastic Limit Percent	Average Depth Range of Horizon, Inches	Engineering Name	Engineering Group Symbol[1]	Public Roads Administration Class symbol[2]	Plasticity Index, Percent	Plastic Limit Percent	Bearing Ratio at Optimum Compaction[4]
Orland Field	11	Elder gravelly loam	0-5	Gravel with fines	GF	A-2	Very slightly plastic to non-plastic		0-72+	Gravelly sandy loam	GF to GW	A-1 to A-2	0-7	Non-plastic to 15	Very High
			5-72+	Poorly graded gravel sand mixture	GP	A-3									
	12	Elder sandy loam and gravelly sandy loam undifferentiated	0-18	Chiefly sand with fines	SF some GF	A-2	Very slightly plastic to non-plastic		0 18	Gravelly sandy loam	GW	A-1 to A-2	0	Non-plastic	Very High
			18-72+	Gravelly sand	SW	A 3			18-72+	Gravelly sandy loam	GW	A-1 to A-2	0-6	Non-plastic to 14	Very High
Fairfield-Suisun Airport	21	Capay loam	0-11	Silty and clayey fine sand	ML	A-4	5 15	15 25	0-18	Clay loam	CL	A-4	10	16	High
			11-45	Silty and sandy clays of medium plasticity	CL	A-6	10-20	15-25	18 38	Clay loam to sandy clay loam	CL	A-6	19-21	16	Not Tested
			45-72+	See footnote 5	ML, CL some SF	A-4, A-6 some A-2	<20	15-25	38-72+	Clay	- - -	- - - - -	Not Tested	- -	- - - -
	22	Capay silty clay loam	0-45	Plastic inorganic silty clay	CL	A-7	10-25	15-25	0-18	Clay loam	CL	A-4	10	14	Medium
			45-72+	See footnote 5	ML, CL some SF	A-4 A-6 some A-2	<20	15-25	18-84	Clay	CL	A-6	25-32	20-21	Medium
	31	Olcott fine sandy loam	0-17	Clayey fine sand	ML	A-4	<10	18-25	0-16	Sandy clay	- - -	- -	Not Tested	- - -	- - - -
			17-33	Plastic sandy clay or clay	CL	A-6, A-7	15-25	20-28	16-80	Sandy loam	ML	A-2	0	Non-plastic	High
			33-72+	Interbedded semi-consolidated clay and sand	CL, SP interbedded	A-6, A-3	<15	15-25							
	41	Antioch fine sandy loam	0-18	Clayey fine sand	ML	A-4, A-6	5-15	12-20	0-8	Sandy loam to loam	SF	A-2	3-4	15-17	Very High
			18-33	Plastic clay	CL, CH	A 7	15-25	16-24	8-34	Clay	CL	A 7	24-30	18-19	Medium
			33-43	Silty sandy clay	CL	A-6	5 20	15 22	34-54	Loamy sand	ML	A-2	0	Non-plastic	Not Tested
			43 72+	Clayey sand to sandy clay	ML, CL	A-4 A-6	<20	15 25	54-96	Sandy loam to loam	CL	A-4	12-15	17-21	Very low to medium
	51	Solano fine sandy loam	0-12	Clayey fine sand	ML	A-4	<10	12-18	- - -	- - - -	- -	- - - - -	Not Sampled	- -	- - - -
			12-72+	Sandy clay and clay	CL	A-4, A-6	10-25	16-20	- -	- -					
Kingsbury	61	Merced Sandy loam	0-11	Poorly graded sand and sand with fines	SP, SF	A-3 A-2	Very slightly plastic to non-plastic		0-8	Sandy loam	SF	A-2	0	Non-plastic	Medium to high
			11-33	Sand with fines, compact	SF	A-2			8-47	Sandy loam to sandy clay loam	SF	A-2	0-3	Non-plastic to 15	Medium to high
			33-72+	Sand with fines	SF	A-2			- - -	- - - -	- - -	- - - - -	Not Sampled	- - -	- - - -
Stockton Field	71	Stockton clay	0-11	Highly plastic clay	CH	A-7	20-35	16-24	0-12	Black adobe	CH	A-7	28-37	16-25	Very low
			11 30	Highly plastic clay	CH	A-7	25-40	20-30	12 36	Black adobe	CH	A-7	37-46	17-22	Very low
			30-72+	Silty and sandy clay	CL	A-6 A-7	10-20	15-25	36-60	Clay to clay loam	CL	A 7	10-22	21-29	Very low to medium
Merced	81	San Joaquin sandy loam	0-20	Poorly graded sand clay mixtures	SF, ML	A-2 A-4	<8	10-18	0-42	Sandy loam	SC	A-2	0-6	Non-plastic to 11	High to very high
			20-38	Sandy clay and clay	ML, CL	A 4 A-6	5-15	15-25	42-48	- - - - -	- -	- - -	Not sampled	- - -	- - -
			38-72+	Hardpan	- -	- - -	-	- -	48-60	Sandy Hardpan	- - -	- -	0	Non-plastic	- - - -
	91	Madera sandy loam	0-8	Clayey sand	CL	A-4	<5	10-18							
			8-42	Silty and Clayey fine sand	CL	A-4	5-15	12-20	- - -	- - - - -	- - -	- - - -	Not sampled	- - -	- - - -
			42-72+	Hardpan	- -	- - -	-	- -							

[1] See footnote 1, Table 2

[2] See footnote 2, Table 2

[3] Data taken from the files of the Materials and Laboratory Section of the U S Engineer Office, Sacramento District

[4] Adjectives refer to quality for subgrade

[5] Soil material estimated to show wide differences in character in this depth range

liminary assessment of airfield sites, estimates were made of the engineering properties and construction problems of certain soil types in central California, upon which airfield runways had been constructed for Army use.

The estimates were undertaken without knowledge of the results of tests made upon the soils in the U. S. Engineer Laboratory and depended entirely upon published U. S. Department of Agriculture and University of California soil survey reports, U. S. Geological Survey topographic maps, and literature in the fields of soil physics and mechanics. The engineering laboratory results, classification categories and construction experience were then examined for the purpose of comparing them with, and evaluating, the independent interpretations and estimates which had been made.

The estimates and laboratory examinations included engineers' classification categories as used by the Corps of Engineers and the Public Roads Administration, expansion, shrinkage and permeability. Numerical estimates were made only for ranges in values of plastic limit, plasticity index and bearing ratio, for which three properties, as well as for expansion and shrinkage, quantitative measurements had been made in the engineering laboratory.

Agreement between estimates and determinations was close for all properties except ranges in bearing ratio but, despite discrepancies in magnitude, the relative positions of the soils with respect to their bearing ratios were similar and conclusions concerning the suitability of the soils for subgrade material were the same whether based upon estimated or laboratory values. There was also found to be close agreement between the estimated and experienced field construction problems.

It is concluded that the proper interpretation of the information contained in agricultural soil survey reports can be used to excellent advantage in the selection and preliminary assessment of sites prior to engineering construction. It is evident that the best that can at present be expected in the estimate of engineering properties of soils is a qualitative expression or, for certain properties, a correct range in numerical values. There is no substitute for a detailed engineering survey of the selected site and appropriate sampling, with due regard to existing soil maps, soil types and known conditions, followed by engineering laboratory measurements and investigations aimed at rational design.

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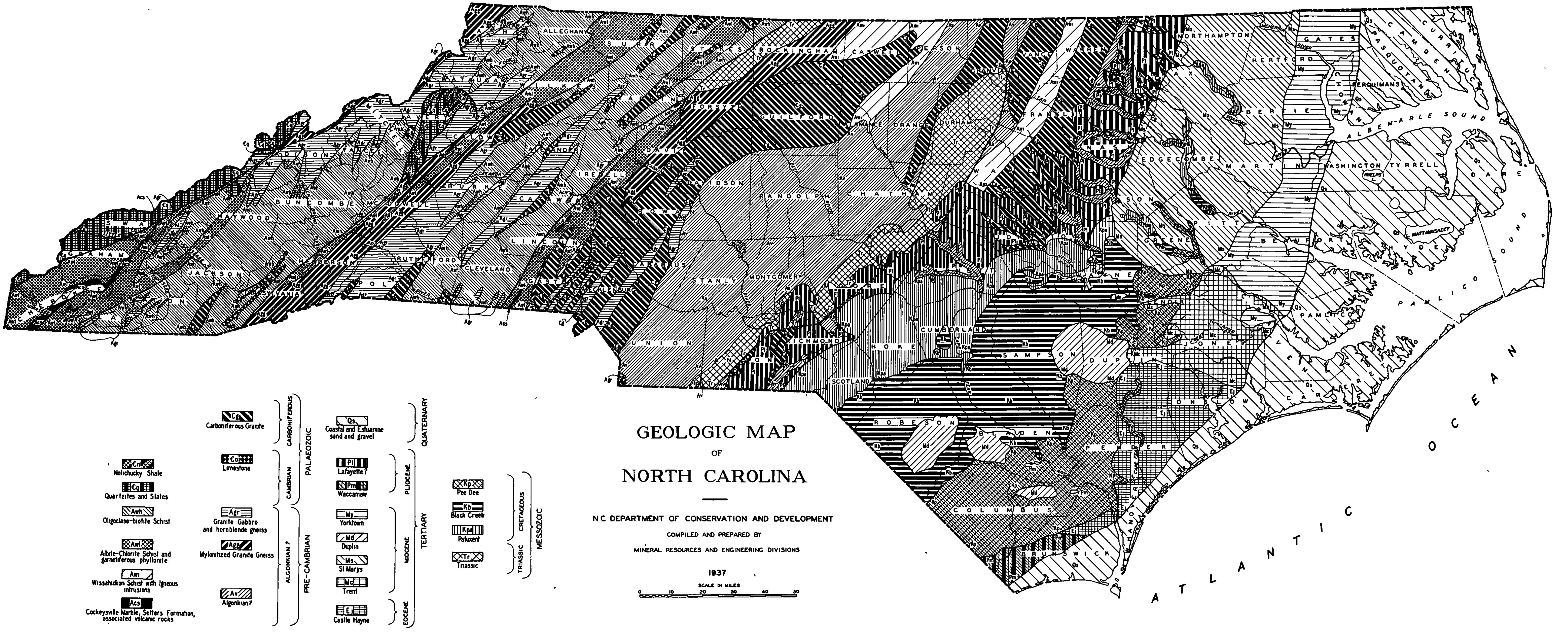

GEOLOGIC MAP

OF

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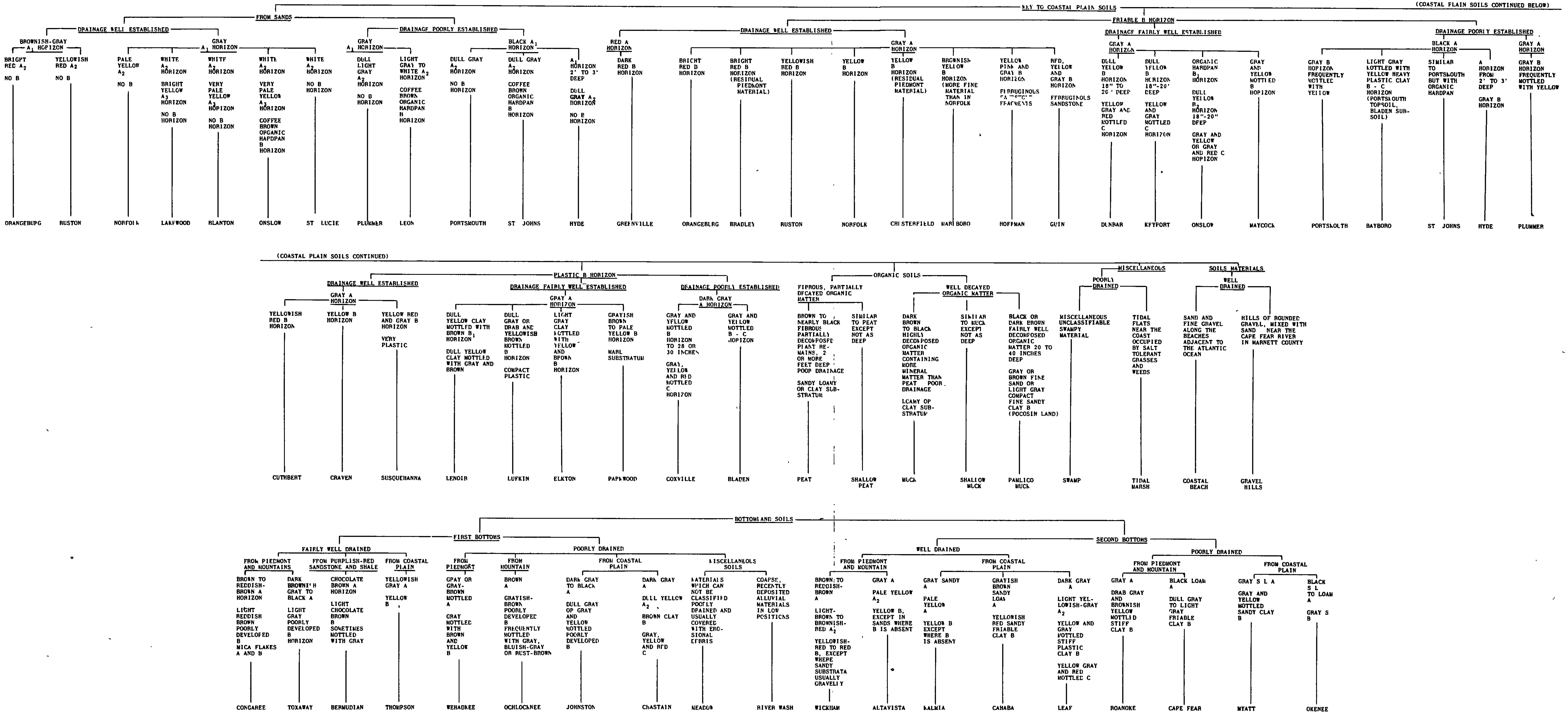
N C DEPARTMENT OF CONSERVATION AND DEVELOPMENT

COMPILED AND PREPARED BY

MINERAL RESOURCES AND ENGINEERING DIVISIONS

1937



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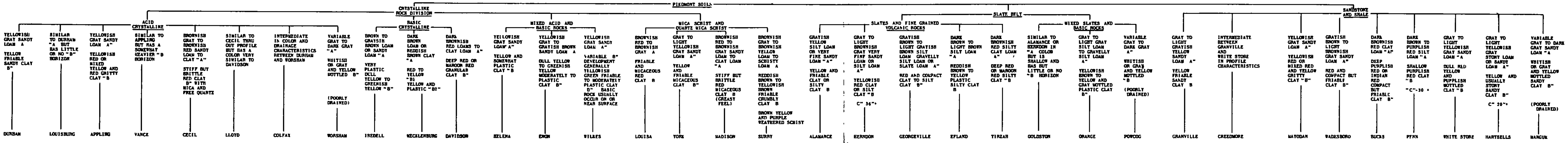

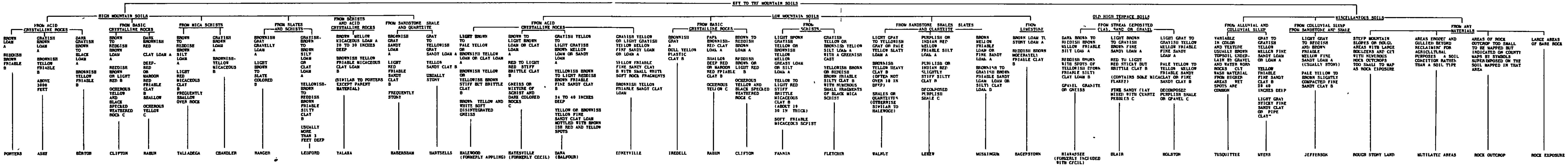

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