A GENERALIZED INVESTIGATION OF POTENTIALLY POOR SOIL SUPPORT BY REGIONAL GEOMORPHIC UNITS WITHIN THE CONTERMINOUS 48 STATES

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This report qualitatively assesses the potential for poor soil support within the conterminous 48 states. For each of 97 physiographic sections, an estimate was made of (a) the frequency of occurrence of organic deposits and (b) the combined frequency of occurrence-severity rating of clayey deposits. In order to assess the regional character of the poor support problem, a national soil textural map was developed. Frequency of occurrence ratings for organic deposits were determined directly from this map for each section. For clayey deposits, a severity scale, based on a relationship between the soil texture and the Unified Soil Classification System, was combined with the frequency of occurrence rating of clayey deposits obtained from the national soils map. The study indicated the limited regional distribution of organic terrain in the 48 states. This distribution is concentrated in youthful (geomorphic) glacial and coastal terrain due to the rather poorly integrated drainage system often associated with these regional geomorphic areas. Although clayey deposits occur throughout the 48 states, most are found east of the Rocky Mountains because the climatic, topographic, and parent material factors are generally more favorable there.

ALTHOUGH engineering design and construction decisions are unique solutions to specfic problems, these decisions may depend strongly on the store of highly relevant experiences that engineers use as background or perspective input. The requisite input for highway design and construction decisions is developed through a process of convergence, for example, by moving from a general understanding of a large piece of geography to the specifics of a site or route that is no more than a point or a thin line on any but a very large-scale map.

The search for geographic units that demonstrate significant homogeneity in ground conditions, other environmental factors, engineering problems, and design and construction practice has led a number of engineers to study the work of physiographers and regional geomorphologists. These scientists classify and map areas on the basis of their mode of topographic expression, which in turn depends principally on the factors of structure, process, and stage. Because these factors can be practically interpreted as parent material, origin, and age (19), it is not surprising that physiographic mapping is useful. The mapped units of interest to engineers are the province, the section, and the subsection.

The objective of this paper is to report an investigation of the distribution of soils that afford potentially poor support for highway structures and the correlation of this distribution to an extant system for the conterminous 48 states. Two general soil categories were identified as providing "poor" support: organics and clays. The organics are extremely poor as foundations for embankments or other structures and are, of course, unacceptable as subgrade or embankment materials (except in certain non-

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critical portions of the embankment). The clays are potentially troublesome as foundations or in compacted layers because of their low permeability and their sensitivity to changes in water content, which cause changes in strength and volume.

The classification selected was a slightly modified version of the Woods-Lovell Engineering-Physiographic System presented in 1960 (17), which has 97 "unique" areas (physiographic sections). Table 1 lists each section and provides a code for its location shown in Figure 1.

METHOD OF ANALYSIS

The qualitative evaluation of potentially poor soil support areas within each section was based primarily on a national soil texture map, developed by the senior author and used in conjunction with the map of physiographic sections. For the clayey soils a combined severity-frequency rating was devised, whereas for the organics ratings were based on the relative frequency of occurrence.

The following portions of this paper briefly describe the methods used (a) to develop the soils texture map and (b) to obtain an estimate of the magnitude of the poor soil support problem within each of the 97 sections composing the conterminous 48 states.

Soil Texture Map

The generalized soil textural map of the United States was developed to a scale of 1:2,500,000, which corresponds to the scale of the national geologic map (11) as well as the pedologic map (4).

Many references were consulted in the preparation of the map. Principal among these were reports and mappings of soil distribution for national, regional, and state coverage. The national group included several references (5, 6, 9, 13, 17, 18). Regional soil references were available for the western United States (16), north central region (12), southeast region (14), and the northeastern United States (10). Many individual state soil maps were frequently consulted for soil data. The references varied widely in content and date of preparation; e.g., only old coverage was available for some geographic areas (7, 8), whereas very current information was located for others (3, 15).

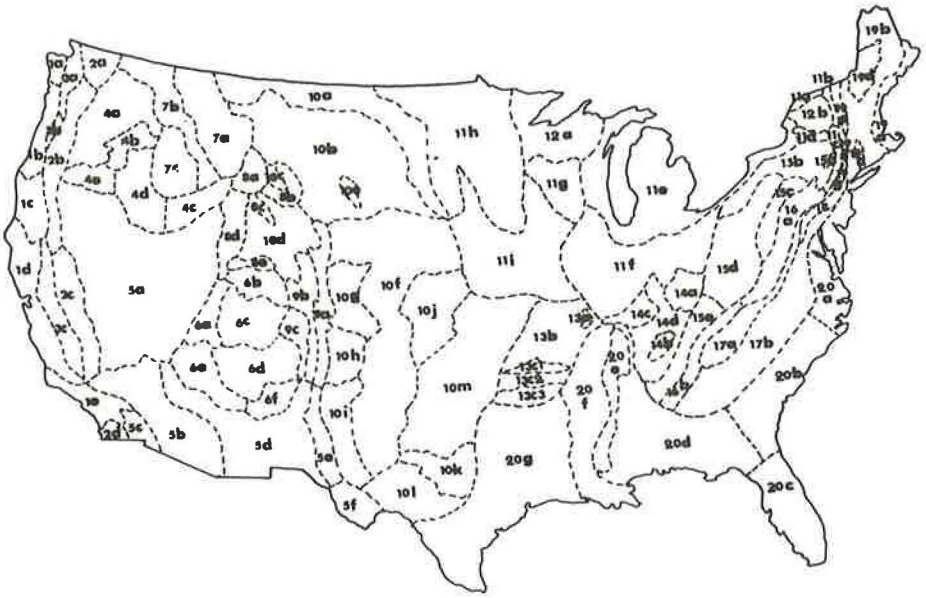

Figure 1. Physiographic diagram of the United States.

TABLE 1

PHYSIOGRAPHIC UNIT CODE

1. Western Mountains of the Pacific Coast Range
   a. Olympic Mountain
   b. Oregon Coast Range
   c. Klamath Mountain
   d. California Coast Range
   e. Los Angeles Range
2. Sierra-Cascade
   a. Northern Cascade Mountain
   b. Southern Cascade Mountain
   c. Sierra Nevada
   d. Lower California
3. Pacific Troughs
   a. Puget Sound
   b. Willamette Valley
   c. California Valley
4. Columbia Plateau
   a. Walla-Walla
   b. Blue Mountain
   c. Snake River Plains
   d. Payette
   e. Harney
5. Basin and Range
   a. Great (Closed) Basin
   b. Sonoran Desert
   c. Salton Trough
   d. Open Basin (Mexican Highland)
   e. Sacramento Highland
   f. Great Bend Highland
6. Colorado Plateau
   a. High Plateaus of Utah
   b. Uinta Basin
   c. Canyon Lands
   d. Navajo
   e. Grand Canyon
   f. Datil
7. Northern Rocky Mountain
   a. Montana
   b. Bitteroot
   c. Salmon River
8. Middle Rocky Mountain
   a. Yellowstone
   b. Bighorn Mountain
   c. Wind River Mountain
   d. Wasatch
   e. Uinta Mountain
9. Southern Rocky Mountain
   a. Front Range
   b. Western
   c. San Juan Mountain
10. Great Plains
    a. Glaciated Missouri Plateau
    b. Unglaciated Missouri Plateau
    c. Bighorn Basin
    d. Wyoming Basin
    e. Black Hills
    f. High Plains
    g. Colorado Piedmont
    h. Raton Upland
    i. Pecos Valley
    j. Plains Border
    k. Central Texas Mineral
    l. Edwards Plateau
    m. Osage Plains
11. Central and Eastern Lowlands
    a. St. Lawrence Lowland
    b. Champlain Lowland
    c. Hudson River Valley
    d. Mohawk River Valley
    e. Eastern Lakes and Lacustrine
    f. Central Till Plain
    g. Driftless
    h. Western Lakes and Lacustrine
    i. Dissected Loessial and Till Plain
12. Laurentian Upland
    a. Superior Upland
    b. Adirondack
13. Ozark and Ouachita
    a. St. Francois Mountain
    b. Springfield-Salem Plateau
    c1. Boston Mountain
    c2. Arkansas Valley
    c3. Ouachita Mountain
14. Interior Low Plateaus
    a. Blue Grass
    b. Nashville Basin
    c. Shawnee Hills
    d. Highland Rim
15. Appalachian Plateau
    a. Catskill Mountain
    b. New York Glaciated
    c. Allegheny Mountain
    d. Kanahwa
    e. Cumberland
16. Newer Appalachian (Ridge and Valley)
    a. Pennsylvania-Maryland-Virginia
    b. Tennessee
17. Older Appalachian
    a. Blue Ridge
    b. Piedmont
18. Triassic Lowland
19. New England Maritime
    a. Seaboard Lowland
    b. New England Upland
    c. Connecticut Lowland
    d. White Mountain
    e. Green Mountain
    f. Taconic
    g. Reading Prong
20. Atlantic and Gulf Coastal Plain
    a. Embayed
    b. Sea Island
    c. Florida
    d. East Gulf
    e. Mississippi Loessial Upland
    f. Mississippi Alluvial Plain
    g. West Gulf

Note: Numbers represent physiographic provinces, letters represent physiographic sections.

TABLE 2

GENERAL SOIL CLASSIFICATION CORRELATION

General Texture	Texture Type	U.S.C.S.[a] Most Probable	U.S.C.S.[a] Other
Coarse	Gravel	GP;GW	GM;GC
	Sand	SM;SP-SM	SM-SC
	Loamy sand	SM	SC
Moderately coarse	Sandy loam	SM	ML;SC
	Fine sandy loam	SM;ML	SM;ML SC;SM
Medium	Very fine sandy loam	SM;ML	
	Loam	CL	ML;ML-CL
	Silt loam	CL	ML;ML-CL
Moderately fine	Sandy clay loam	CL	SC
	Silt	ML	CL
	Silty clay loam	CL	CH
	Clay loam	CL	CH
Fine	Sandy clay	SC;CL	CL
	Silty clay	CH	CL;MH
	Clay	CH	

[a]Unified Soil Classification System.

TABLE 3

GENERALIZED SEVERITY CATEGORY OF POOR SUPPORT POTENTIAL BY TEXTURAL CLASSIFICATION

Category	Textural Classification	Most Probable U.S.C.S. Category	Other U.S.C.S. Categories
1 (least severe)	Sandy clay	SC;CL	
	Sandy clay loam	CL	SC
2	Silt	ML	CL
	Silt loam	CL	ML;ML-CL
	Loam	CL	ML;ML-CL
3	Clay loam	CL	CH
	Silty clay loam	CL	CH
4 (most severe)	Silty clay	CH	CL
	Clay	CH	CL

The mapping technique was designed to retain as much detailed soil information as practicable; this was accomplished by preserving rather adequate descriptions of soil texture. The information available varied from classification by engineering systems to such generalities as "fine textured" or "moderately coarse." Table 2 was developed from other sources (1, 2) to aid in the requisite interpretations and correlations of descriptions.

Every attempt was made to distinguish and map the general texture of the parent material. Within residual soil areas this was not always possible, and major emphasis was placed on the general texture in the subsoil as well as the weathered parent materials.

Organic Deposits

The term organic deposits refers to peat bogs, muck lands, and associated swamps and tidal marshes. The relative frequency of occurrence of these deposits within each physiographic unit was evaluated directly from the national soils texture map. An arbitrary rating code was devised as follows: (VW) very widespread, (M-W) medium-to-widespread, (L-M) limited-to-medium, (N-L) nonexistent-to-limited, and (NE) nonexistent.

Clayey Deposits

Foundation and subgrade problems with inorganic soils are not confined to clays, but a number of difficulties are correlated with clayeyness. Accordingly, the rating of sections was accomplished by a combined consideration of the clayeyness of the soils and the frequency of occurrence of such soils.

The two coarse categories in Table 2, i.e., coarse and moderately coarse, are considered to afford satisfactory support. The finer textures were grouped into four severity categories, based on the most probable Unified Soil Classification given in Table 2; the four categories are given in Table 3.

Severity ratings were then qualitatively formulated for each section by combining distributive information with the general severity categories of Table 3. The arbitrary rating code used the same five descriptors as were used for the organic deposits.

RESULTS

Soil Texture Map

The soil texture map of the United States is shown in six sheets (Figs. 2 to 7). In general, three broad categories of units are mapped: single-textured units, multiple-

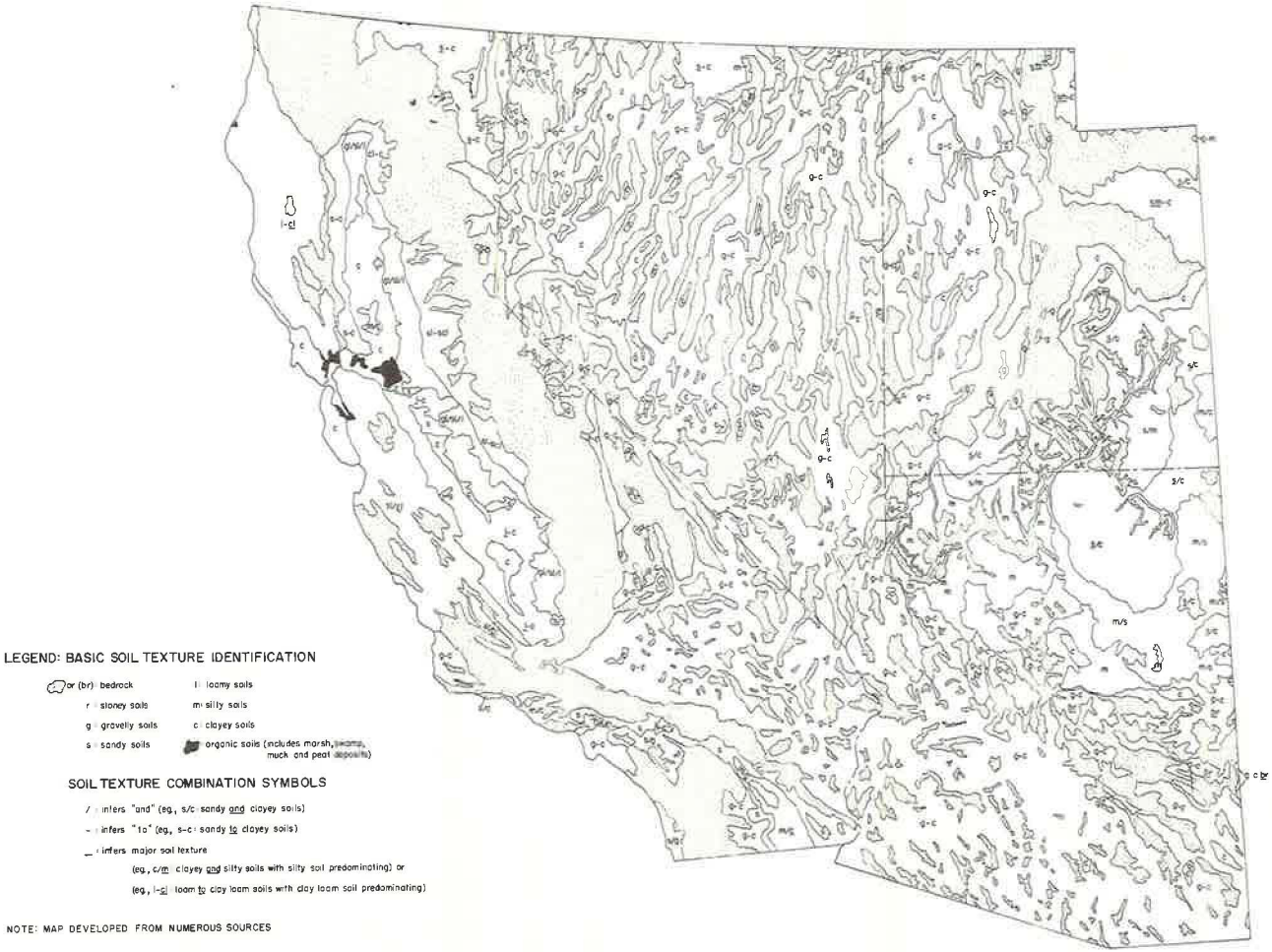

Figure 2. Generalized soil texture map of the continental United States (Map sheet I: southwest United States).

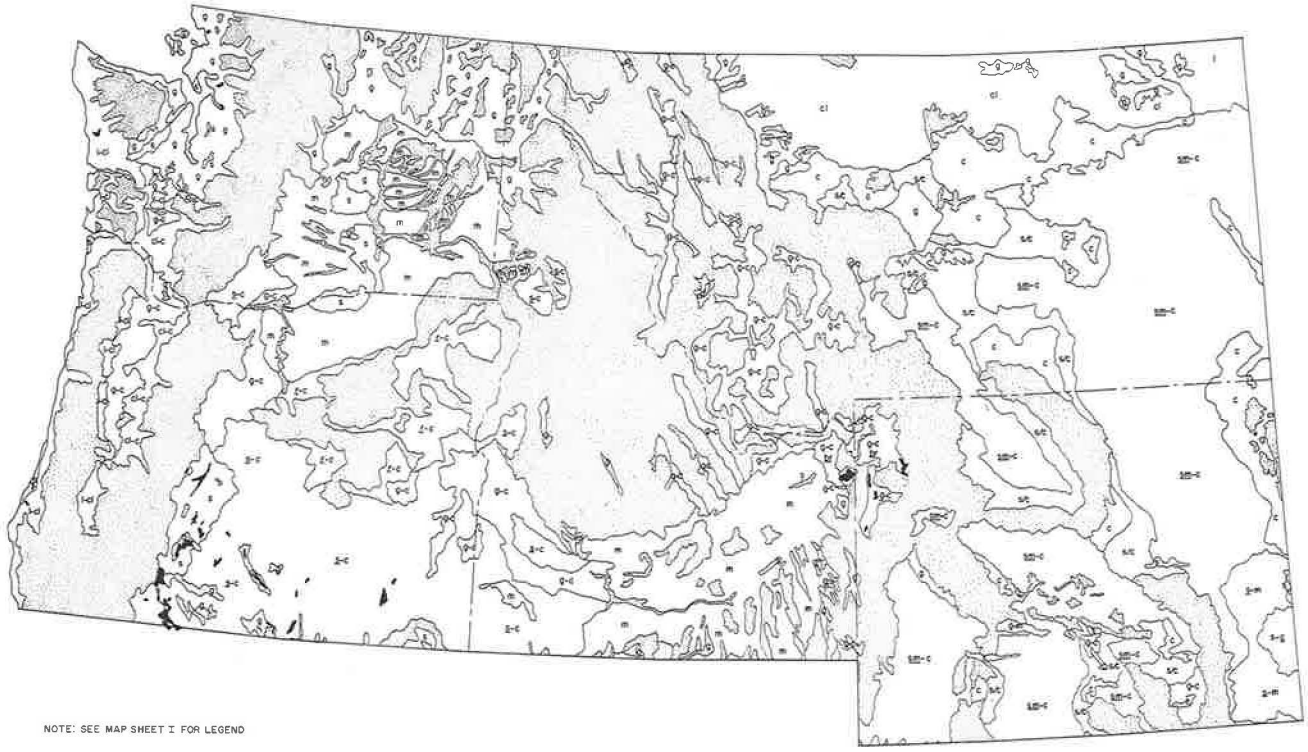

Figure 3. Generalized soil texture map of the continental United States (Map sheet II: northwest United States).

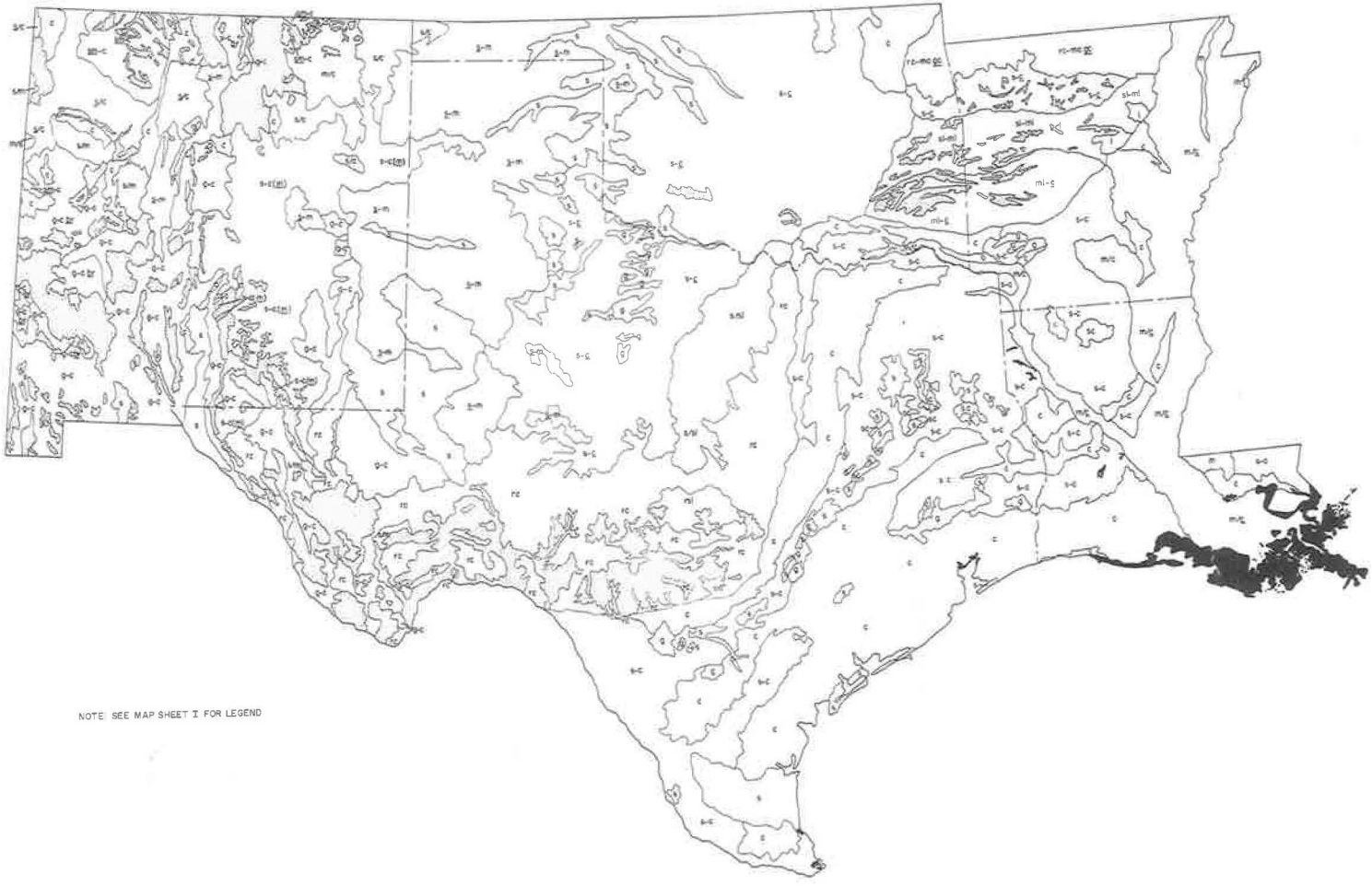

Figure 4. Generalized soil texture map of the continental United States (Map sheet III: south central United States).

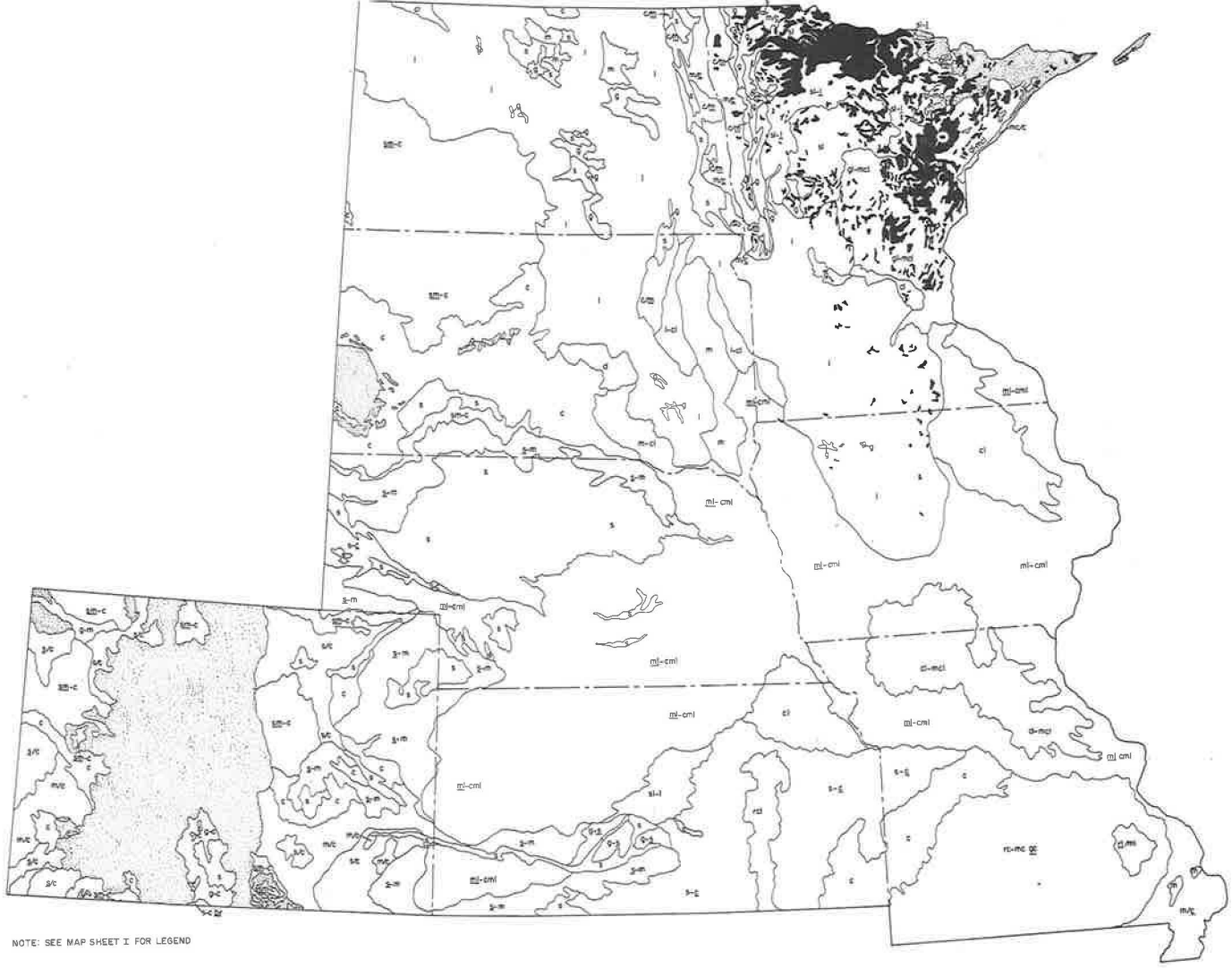

Figure 5. Generalized soil texture map of the continental United States (Map sheet IV: north central United States).

Figure 6. Generalized soil texture map of the continental United States (Map sheet V: southeast United States).

Figure 7. Generalized soil texture map of the continental United States (Map sheet VI: northeast United States).

TABLE 4

SUMMARY OF ESTIMATED FREQUENCY OF OCCURRENCE OF ORGANIC AREAS WITHIN SECTIONS

Nonexistent		Nonexistent-to-Limited		Limited-to-Medium		Medium-to-Widespread		Very Widespread	
Section Code	Area (sq miles)	Section Code	Area (sq miles)	Section Code	Area (sq miles)	Section Code	Area (sq miles)	Section Code	Area (sq miles)
1c,e	41,830	1a,b,d	60,930	–	–	–	–	–	–
2a,b,c,d	90,670	–	–	–	–	–	–	–	–
3b	4,700	3a,c	37,610	–	–	–	–	–	–
4a,b,c,d	99,000	4e	15,850	–	–	–	–	–	–
5a,b,c,d,e	362,690	–	–	–	–	–	–	–	–
6a,b,c,d,e,f	123,920	–	–	–	–	–	–	–	–
7a,b,c	105,780	–	–	–	–	–	–	–	–
8a,b,c,e	28,200	8d	17,140	–	–	–	–	–	–
9a,b,c	60,450	–	–	–	–	–	–	–	–
10a-m	652,840	–	–	–	–	–	–	–	–
11i	89.580	11b,c,d,f,g	114,730	11a,h	100,590	11e	88,010	–	–
–	–	–	–	12a,b	72,540	–	–	–	–
13a,b,c1,c2,c3	66,490	–	–	–	–	–	–	–	–
14a,b,c,d	51,380	–	–	–	–	–	–	–	–
15a,c,d,e	80,260	15b	22,500	–	–	–	–	–	–
16a,b	45,340	–	–	–	–	–	–	–	–
17a,b	90,670	–	–	–	–	–	–	–	–
–	–	18	6,040	–	–	–	–	–	–
19e,f,g	8,760	19b,c,d	48,940	19a	11,820	–	–	–	–
20e	22,860	20d,f,g	278,420	20a,b	87,180	20c	34,680	–	–
Total	2,025,420		602,160		272,130		122,690		0
Percentage of 48 states	67.0		19.9		9.0		4.1		0

textured units, and gradationally textured units. When soil types occur in combination, and one is known to dominate, it is underlined in the designations. The legend for the soil types is shown in Figure 2 and is self-explanatory.

Organic Deposits

Table 4 summarizes the frequency of occurrence of organic deposits by sections. Figure 8 shows the distribution of the summary table. In addition, the soil texture maps (Figs. 2 to 7) illustrate the actual regional distribution of these deposits.

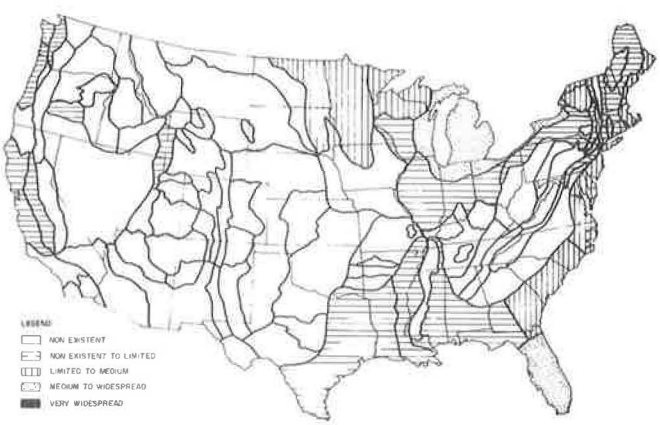

Figure 8. Estimated frequency of occurrence of potential poor subgrade support areas (organic deposits) by physiographic unit.

Clayey Deposits

Table 5 summarizes the estimated frequency of occurrence-severity rating of clayey soils within each section, and Figure 9 shows the geographic distribution of the ratings. The actual regional distribution may be deduced from Figures 2 through 7.

TABLE 5

SUMMARY OF ESTIMATED FREQUENCY OF OCCURRENCE-SEVERITY RATING OF CLAYEY SOIL AREAS WITHIN SECTIONS

Nonexistent		Nonexistent-to-Limited		Limited-to-Medium		Medium-to-Widespread		Very Widespread	
Section Code	Area (sq miles)	Section Code	Area (sq miles)	Section Code	Area (sq miles)	Section Code	Area (sq miles)	Section Code	Area (sq miles)
1c	20,040	1a,b,e	44,180	1d	38,540	—	—	—	—
2a,d	22,940	2b,c	67,730	—	—	—	—	—	—
—	—	3a	14,510	3b	4,700	3c	23,100	—	—
4a,b,c,e	94,290	4d	20,560	—	—	—	—	—	—
—	—	5b,d,e,f	176,630	5a	175,540	5c	10,520	—	—
—	—	6a,b,c,d,e	114,630	6f	9,290	—	—	—	—
7b,c	61,980	7a	43,800	—	—	—	—	—	—
8a,b,c,e	28,200	8d	17,140	—	—	—	—	—	—
9a,b,c	60,450	—	—	—	—	—	—	—	—
—	—	10c,d,e,f,i,j,k	268,310	10a,g,h,1	150,160	10b,m	234,370	—	—
—	—	11g,h	119,060	11d,e	90,370	11a,b,c,f,i	183,480	—	—
12b	8,990	12a	63,550	—	—	—	—	—	—
—	—	13a,c2	12,300	13b,c1,c3	54,190	—	—	—	—
—	—	—	—	14c	16,540	14d	23,580	14a,b	11,260
—	—	15a,e	23,640	15b,c	33,190	15d	45,930	—	—
—	—	—	—	16a,b	45,340	—	—	—	—
17a	19,770	—	—	—	—	17b	70,900	—	—
—	—	—	—	—	—	18	6,040	—	—
19c,d,e,g	20,160	19b,f	37,540	—	—	19a	11,820	—	—
—	—	20a,b,e	110,040	20c,d	126,920	20g	140,480	20f	45,700
Total	336,820		1,133,620		744,780		750,220		56,960
Percentage of 48 states	11.2		37.6		24.5		24.8		1.9

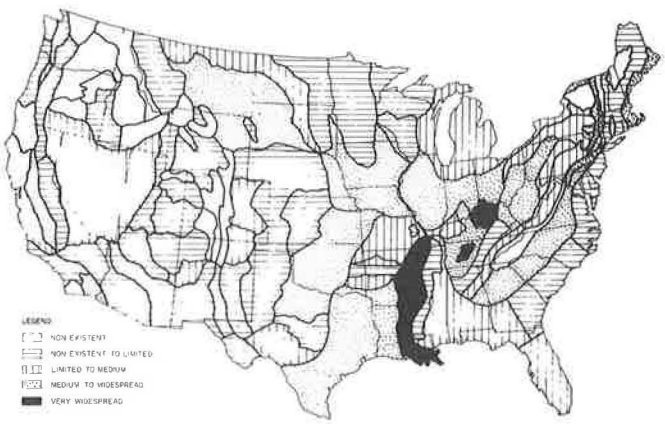

Figure 9. Estimated frequency of occurrence-severity rating of potential poor subgrade support areas (inorganic/clayey deposits) by physiographic unit.

SUMMARY AND CONCLUSIONS

Organic Deposits

The occurrence of organic deposits is relatively limited in the United States. As can be noted from Figure 8, physiographic sections composing an area of almost 87 percent of the conterminous 48 states have, at most, a nonexistent-to-limited rating.

The greatest frequency ratings occur for the Eastern Lakes and Lacustrine Plains Section of the Central and Eastern Lowland Province, and the Florida Section of the Atlantic and Gulf Coastal Plain Province. It is within these two geomorphic conditions-glaciation and coastal plain development—that organic-type terrain becomes a significant factor in highway engineering.

Table 6 summarizes the sections possessing organic deposits, grouped by the major geomorphic modes of occurrence. A salient geomorphic condition for organics is associated with youthfulness on transported deposits. This is due in part to the fact that youthful terrains are often associated with poorly integrated drainage systems.

TABLE 6

SUMMARY OF SECTIONS POSSESSING ORGANIC DEPOSITS GROUPED BY MAJOR GEOMORPHIC MODES

Section Code	Rating[a]	Remarks
I. Glaciated Areas		
Puget Trough (3a)	N-L	
Wasatch (8d)	N-L	found with glacial outwash in Jackson Hole area
Champlain Lowland (11b)	N-L	
Hudson River Valley (11c)	N-L	
Mohawk River Valley (11d)	N-L	
Central Till Plain (11f)	N-L	
St. Lawrence Lowland (11a)	L-M	
Western Lakes and Lacustrine (11h)	L-M	
Eastern Lakes and Lacustrine (11e)	M-W	
Superior Upland (12a)	L-M	
Adirondack (12b)	L-M	
New York Glaciated (15b)	N-L	
Triassic Lowland (18)	N-L	associated with northern glaciated area
New England Upland (19b)	N-L	
Connecticut Lowland (19c)	N-L	
White Mountain (19d)	N-L	
Seaboard Lowland (19a)		
II. Coastal and Embayed Areas		
Oregon Coast Range (1b)	N-L	found within small coastal plain areas of Oregon
California Coast Range (1d)	N-L	associated with section 3c within San Francisco Bay area
California Valley (3c)	N-L	associated with section 1d within San Francisco Bay area
East Gulf Coast (20d)	N-L	occurs primarily in outer coastal plain
West Gulf Coast (20g)	N-L	occurs primarily in outer coastal plain
Embayed (20a)	L-M	
Sea Island (20b)	L-M	
Florida (20c)	M-W	possesses largest swamp area in United States
III. Deltaic Areas		
Mississippi Alluvial Plain (20f)	N-L	associated with Mississippi delta area

[a]N-L = nonexistent-to-limited; L-M = limited-to-medium; M-W = medium-to-widespread.

Clayey Deposits

Table 5 indicates that more than 26 percent of the 48 states have a frequency of occurrence-severity rating of clayey soils more severe than limited-to-medium. Perhaps even more significant is the obvious concentration of clayey areas in the eastern province grouping. (The western province grouping consists of physiographic units having a code prefix of 1 through 9; units composing the eastern grouping are prefixed by numbers 10 through 29.) Approximately 75 percent of the western province grouping area possesses sections having a rating less than or equal to a nonexistent-to-limited severity, whereas only slightly more than 3 percent of the area has sections showing a medium-to-widespread or greater rating. In contrast, in the eastern group almost 40 percent of its area has sections with a medium-to-widespread or greater rating.

There are several probable reasons for this pattern, each perhaps interrelated to the others. It is felt that the major factors are the following:

1. The climatic environment (humid type) prevalent in the East is more conducive to chemical weathering processes that generally are associated with clay development in contrast to physical weathering.
2. The overall topographic features (elevation, relief) of the eastern United States are similarly more favorable for chemical weathering in combination with the climatic regime of the area.
3. The groupings of origin-parent material types in the East are conducive to clay deposition and/or development. Within the glaciated northern portion of the area, the most highly plastic soils are generally associated with water deposition of glacial lacustrine or marine origin. Similarly the clays of the coastal plain are primarily found associated with either the coastal limestones and chalks or widespread fine-grained alluvial deposition. Within these two zones is the consolidated bedrock region that is composed primarily of sedimentary types, in which clayey-type residua are often developed within the climatic and topographic environments peculiar to this region.

Although the physiographic sections used in the analysis are useful in the ratings of poor soil support, they are generally too large and variable to serve the desired purpose. Subsequently, a system of 242 subsections has been developed (19), which should permit more accurate and detailed predictions.

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