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Report ETL-SR-72-1

POTENTIAL SAND AND DUST SOURCE AREAS
(Report No. 1 of "Studies of the Army Aviation V/STOL Environment")

by

Howard L. Ohman, John Viletto, Jr.,
Kenneth T. Anderson, and L. LeForest Miller

August 1972

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U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA

37

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Distributed by

The Commanding Officer
U. S. Army Engineer Topographic Laboratories

Prepared by

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Earth Sciences Division
Geographic Sciences Laboratory
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Soil Conservation Service
U. S. Department of Agriculture

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I-C

SUMMARY

This study delineates world patterns of various soil types that have a potential for the generation of atmospheric sand and dust either through natural causes or man-induced mechanical agitation. This is done by three maps: one showing soil types as determined by classes of particle size; a second showing seasonal durations of wet, moist, and dry soil conditions; and a third portraying the distribution of siliceous, vitreous, saline, and acidic soils, soils with high percentages of iron and aluminum, and soils consisting largely of montmorillonitic clays.

The maps provide the basis for a realistic assessment of Army aircraft design problems which can be attributed to sand and dust. Additionally, they contribute to the total store of environmental information needed to determine the environmental criteria to be adopted in the design and testing of Army V/STOL aircraft systems.

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13. ABSTRACT

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Soil texture						
Moisture regime						
Mineralogy						
Sand and dust						
Soil particle						
Silica						
Titanium						
Montmorillonite						

I-B

FOREWORD

This report is the first in a series programmed by the Earth Sciences Division, U. S. Army Engineer Topographic Laboratories (ETL), to delineate those parameters of the natural environment having operational significance to Army Aviation (V/STOL) aircraft during times of hover, landing, and takeoff. The information will permit the requesting agency, the Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, to make a realistic determination of the criteria to be adopted as environmental standards in the design and testing of Army Aviation (V/STOL) aircraft systems.

This study was produced in response to Reimbursable Service Number RO 72-10, a services directive that prescribes the types of information required to assess fully the significance of sand and dust as design factors.

The Soil Conservation Service, U. S. Department of Agriculture, has been extremely cooperative in providing the basic data from their extensive files on sand and dust and in preparing the maps of this study in accordance with ETL specifications.

CONTENTS

POTENTIAL SAND AND DUST SOURCE AREAS

I. INTRODUCTION

This study is concerned primarily with the distributional aspects of sand and dust sources that are potentially deleterious to V/STOL aircraft during times of hover, landing, and takeoff. Essentially, it is a map study designed to: (1) classify soil types in accordance with scalar degrees of particle size, moisture content, and selected physical and chemical characteristics; and (2) show the global distribution of the various "duster" types of soil, as defined in (1), on maps of suitable scale. The resultant maps are presented as Plates I, II, and III, in the rear pocket of this report.

The physical and chemical characteristics of the various soil types are touched on but briefly here. Only enough information is given to fully elucidate the map presentation. However, the properties of soil particles, insofar as they contribute to the generation of atmospheric dust, are being treated more comprehensively in a companion study currently being prepared on the characteristics of airborne particulate matter.[1]

II. SOIL AS CHARACTERIZED BY PROPERTIES MAPPED

Soil is a composite of mineral particles of various sizes, organic material, water, and air. Of primary importance to this study are the mineral particles and, to a degree, the water or moisture content.

Soil varies greatly in depth from place to place and from region to region. This study, however, concerns itself principally with that portion of the soil cover having critical significance to the generation of dust defined herein as the uppermost 6-inch layer of the soil cover. Only in the discussion of certain selected soil features will the soil below the 6-inch surface layer be considered.

1. **Soil Texture.** The mineral particles comprising a soil are sand, silt, and clay. These particles range in size from the coarse sands that are readily visible to the naked eye to the fine clays which are visible only with the aid of special microscopes. The range in particle diameter for each of these categories is shown in Table I.

[1] J. Viletto and H. L. Ohman, "Particulate Matter Considerations in the Design of V/STOL Aircraft," Report No. 2 of *Studies of the Army Aviation (V/STOL) Environment*, USAETL Technical Report (in process).

Table I. Range in Particle Diameter

Particle	Size Range	
	Micrometers (µm)	Millimeters (mm)
Sand	2000 – 50	2.0 – 0.05
Silt	50 – 2	0.05 – 0.002
Clay	Less than 2	Less than 0.002

In general, a soil is a mixture of particles of various sizes. Only a few kinds of soil consist of particles of a single grain size or size range; such soils commonly are associated with landscape features resulting from the buildup of water- or wind-deposited particles, e.g., the clean sands of beaches, aeolian[2] sands in desert dunes, and the silts of loessial deposits.[3]

The relative proportions of sand, silt, and clay comprising a soil determine the textural class of that soil. For example, a soil which consists of 75 percent sand-size particles, 15 percent silt-size particles, and 10 percent clay-size particles would be called a loamy sand.[4] The texture classes of soils and their percentage size range composition are tabulated in Table II.

Table II. Textural Class and Range in Composition

Textural Class	Range in Composition (percent)		
	Sand	Silt	Clay
Sand	85 – 100	0 – 15	0 – 10
Loamy sand	70 – 85	0 – 30	0 – 15
Sandy loam	52 – 85	0 – 52	0 – 20
Loam	23 – 52	28 – 50	7 – 27
Silt	0 – 20	80 – 100	0 – 12
Silt loam	0 – 50	50 – 80	0 – 28
Silty clay loam	0 – 20	40 – 72	27 – 40
Silty clay	0 – 20	40 – 60	40 – 60
Sandy clay loam	45 – 80	0 – 28	20 – 35
Sandy clay	45 – 65	0 – 20	35 – 55
Clay loam	20 – 45	15 – 52	27 – 40
Clay	0 – 45	0 – 40	40 – 100

[2] A term applied to deposits arranged by the wind.

[3] A sediment, commonly nonstratified and unconsolidated, composed dominantly of silt-size particles, deposited primarily by the wind.

[4] The term "loam" as it appears in this report has limited meaning. It is used to help identify specific textural classes, each of which is defined in terms of the percentage content of sand, silt, and clay. The term is not intended to convey any implication of material content other than the mineral particles comprising the soil or of special characteristics other than those specified for a particular textural class.

The textural classes and their sand, silt, and clay portions are shown graphically in the textural triangle, "Soil Texture Classes." The graph and the percent composition of each of the textural classes shown have been adapted from similar methodology described in the Soil Survey Manual, USDA Handbook No. 18, U. S. Department of Agriculture, 1951.

Sand soils are classified as coarse, medium, or fine depending on the percent composition or "mix" of the various grain sizes within the soil:

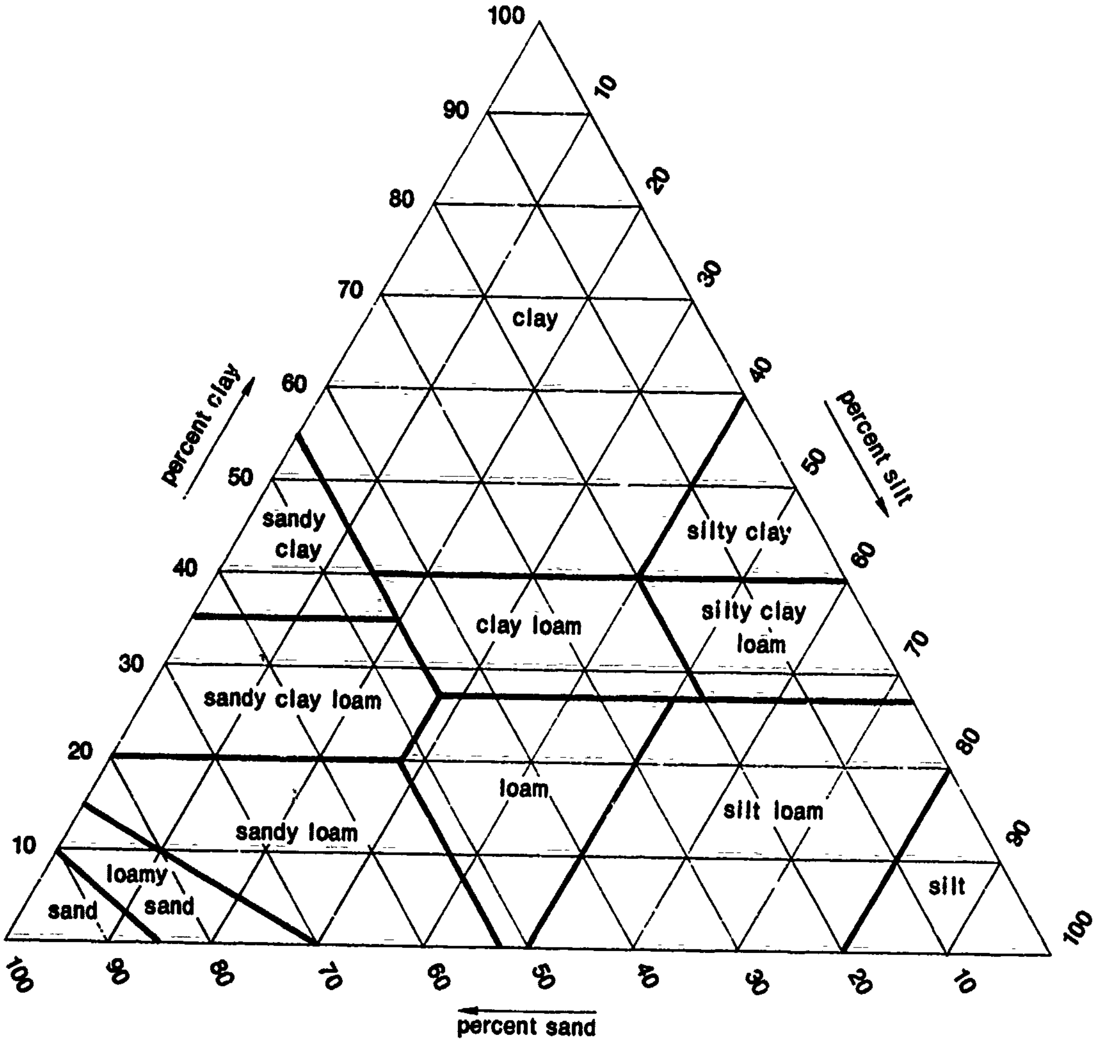
Coarse sand – 25 percent or more of the sand particles are 2000 to 500 micrometers (2.0 to 0.5 mm) in size, and less than 50 percent of the sand particles are of any other single size range.

Medium sand – 25 percent or more of the sand particles are 2000 to 250 micrometers (2.0 to 0.25 mm) in size, and less than 50 percent of the sand particles are 250 to 50 micrometers (0.25 to 0.05 mm) in size.

Fine sand – 50 percent or more of the sand particles are 250 to 50 micrometers (0.25 to 0.05 mm) in size.

Insofar as the mineralogy of sand is concerned, it is generally uncomplicated. Sand frequently appears in the form of particles of silica (SiO_2) as is the case at many mid-latitude beaches where quartz sands characteristically line the landward margins of the tidal zone. Less frequently, sand occurs as particles of gypsum (sulphate of calcium), as is characteristic of certain sand dune areas of Arizona and California, or calcium carbonate, the parent material for the sands of many coral island beaches. On the other hand, the mineralogy of sand can be quite complex, sometimes being extremely varied as in the case of certain volcanic sands that consist of particles of several different minerals.

The world-wide distribution of textural classes of the topmost 6 inches of soil is shown on Plate I, SOILS: SURFACE TEXTURES. Each delineation of the map is identified by a one-, two-, or three-part symbol, each representing a textural class, or in certain cases, either organic material or areas generally devoid of soil cover. Where more than one textural class and/or surface condition such as the lack of a soil cover has been identified within a delineation, the textural class or surface condition considered to be dominant with respect to areal representation is identified first in the sequence of symbols. The next, or second, symbol identifies the codominant or subdominant textural class or surface condition. In some instances, a third symbol is used to identify important



SOIL TEXTURE CLASSES*
Proportion of Sand, Silt, and Clay

* Adapted from Soil Survey Manual, USDA Handbook No. 18, U. S. Department of Agriculture, 1951.

but least significant textural classes and/or surface conditions deemed necessary for depiction in code form.

Because of the very small scale of the map and because soils can vary greatly within short distances, the textural class, or classes, shown for any specific delineation must be recognized as that most commonly occurring within the specific geographic area. Surficial soils of other textural classes can also be expected within the same geographic area but are characteristic of a smaller proportion thereof.

2. **Particle Shape.** Soil particles can be grossly characterized as angular, rounded, or flat. Sands are characteristically angular or rounded, the shape being dependent on the amount of abrasion to which the sand particle has been subjected. Silt particles are also angular or rounded, being similar to sand particles except for their extremely small size. Clay particles are characteristically flat. The sand and silt particles tend to retain their angular shape as long as they are not subjected to abrasion, particularly during movement by water or wind. Abrasive action generated by moving water in streams and oceans and by desert winds rounds the initially sharp angular forms and, in the extreme, ultimately results in rounded particle shapes.

On Plate I, SOILS: SURFACE TEXTURE, a gross delineation between areas of occurrence of predominantly angular versus predominantly rounded soil particles is made. The blac, dotted line extending in an east-west direction across northern United States and northwestern Europe represents the approximate southern limit of glaciation in the northern hemisphere. This line also represents the approximate boundary between a broad region in which sand and silt particles are mostly angular and a considerably larger part of the world in which these particles are mostly rounded. Because the nature of soil varies from place to place and within relatively short distances, this broad characterization of particle shape can be expected to have many exceptions. Those exceptions which apply to more extensive parts of the landscape can be identified.

To the north of the black, dotted line, many of the soils are of glacial origin. They have been moved from their place of origin slowly and with a minimum of abrasive action between particles. As a consequence, the sand and silt particles have retained their original generally angular shape. Particular exceptions to this generality are the soils of stream terraces and flood plains and the soils on beaches and beach ridges. Individual particles of these soils have been subjected to movement in flowing water with the result that the particles gradually assume a polish as they rub against each other. As a consequence, the sand and silt particles in these relatively inextensive and discrete areas tend to be rounded.

To the south of the black, dotted line, the sand and silt particles tend to be rounded. The sands of desert areas in particular are rounded as a result of the movement of the particles along or close to the ground; this action abrades and polishes the grains into more or less rounded shapes. On coastal plains, the sand and silt particles have been moved about at times in the past by water in motion and tend to be similarly rounded. Particular exceptions to these generalizations are the angular sand and silt particles in residual soils, especially those of basaltic origin,[5] which have not been moved far from their place of origin. Commonly, the silt particles in loess deposits are also angular, having been transported by wind without polishing by adjacent particles.

3. **Soil Moisture.** Soil moisture is related to atmospheric moisture but is also affected to varying degree by certain soil properties, such as particle size, structure, and depth, as well as by certain features of the landscape, such as vegetative cover, slope, depth to ground water table, and cultural practices. The relationships are complex and difficult to evaluate.

For purposes of this study, soils are described as wet, moist, or dry. A soil is considered to be wet when the interstices between soil particles are filled or nearly filled with water. A moist soil is one in which the soil particles are covered with a film of water which lines rather than fills the interstices between particles. A soil is considered to be dry when it is devoid of moisture or the interstices are lined with a very thin film of water tightly held by cohesion to the surfaces of the soil particles.

The term "soil moisture regime" related to seasonal changes in the moisture content of the soil over a given period of time– commonly a year. For example, a predominantly moist regime could be one in which the soil is moist from early fall to late spring and dry the remainder of the year; on the average, this sequence of moist and dry conditions can be expected from year to year.

On Plate II, SOILS: MOISTURE REGIMES, six regimes are depicted. The regime indicated for any single delineation is that considered to be most characteristic of the geographic area in question; other moisture regimes can be expected to occur within any single delineation but they could be characteristic of areas too small to be mapped. In temperate and cold regions, soils are frozen for periods of varying length from less than a single day, in some cases, to many months. On the map, characterization of soil moisture regimes in such regions applies to the unfrozen soil..

Inasmuch as only the surface 6 inches of soil are considered in this study, it must be recognized that soil moisturization can vary considerably from day to day as a result of changes in the weather. Actual conditions, therefore, sometimes belie the representations shown on the map which basically are depictions of average seasonal conditions through the year. As a case in point, normally moist soils can be expected to be

[5] Basaltic rock: A fine-grained, dark-colored, igneous rock.

wet for a few hours to as much as several days during and after a period of heavy rain; on the other hand, normally wet soils can become dry during protracted periods of warm, rainless days.

Soils that are wet all or nearly all year (Category 1 on Plate II, SOILS: MOISTURE REGIMES) are likely to have a high ground water table which is at or near the surface of the soil. Seasonal fluctuations in the level of the water table, however, are normal and can be expected in all soil types though variance is greater in some than in others. Wet soils also result from frequent and prolonged flooding either from stream overflow or from accumulation of surface runoff from adjacent slopes. Commonly, soils with this type of moisture regime are characteristic of level or nearly level landscapes. Consequently, the wet all-year or nearly-all-year category is well represented throughout the world.

Soils that are moist all year (Category 2, Plate II) commonly occur where rainfall is so distributed that there are few if any periods when the ground is either saturated or dry and where the weather is cool and evaporation is insufficient to dry the surface of the ground. Soils with this moisture regime are well represented in the high latitudes and poorly represented in the humid tropics.

Usually moist soils which are dry for periods totalling less than 3 months (Category 3, Plate II) are characteristic of regions extending from temperate latitudes to the tropics. These soils are moist most of the year because of a high frequency of rainfall, a relatively low evaporation, or a combination of both. Nevertheless, the soils are dry for periods ranging from a few days to several weeks. Generally, the number of days when the soil is dry does not exceed 90. Commonly, these dry periods occur during the late spring, summer, and early fall in temperate latitudes; however, they can occur at any time of the year in the tropics.

In somewhat drier regions, soils commonly are dry for periods totalling more than 90 days during the year and are moist the remainder of the time (Category 4, Plate II). In monsoon climates, common to some tropical areas, soils are moist for at least one 3-month period during the year and can be expected to be moist for a second period of equal or shorter duration. In the tropics and subtropics, other than those areas with a monsoon climate, soils can be expected to be dry for a total of 3 months or more during the year but they are moist for a total of at least 6 months. Periods when the soils are dry and periods when they are wet are unevenly distributed throughout the year depending on the geographic area.

In comparably dry regions in which there is a marked winter seasonality of rainfall, soils are dry during the summer and moist during the winter (Category 5, Plate II). Soils with this moisture regime characterize parts of western United States, southern and southwestern Australia, and the northern and eastern periphery of the Mediterranean Sea. These soils become dry in late spring or early summer and commonly remain dry until the onset of rains in late summer or early fall.

Soils are dry virtually all year (Category 6, Plate II) in desert and semidesert areas. In regions with this soil moisture regime, rains occur infrequently, if at all, and soils are moist for very brief periods.

4. **Selected Physical and Chemical Properties.** Certain physical and/or chemical qualities of the 6-inch surficial layer of soil tend to compound many of the problems associated with dust production. The degree of hardness of the minerals comprising the soil is related to the abrasiveness of the dust raised by wheels of vehicles and moving external parts of aircraft. In addition, the presence of certain chemical compounds in the soil is particularly conducive to corrosion of metal parts. On Plate III, DISTRIBUTION OF SOILS (SCHEMATIC) WITH SELECTED PHYSICAL AND CHEMICAL FEATURES, broad regions are shown in which soils with properties particularly deleterious to military equipment represent a sufficient percentage of the total land surface to be a potential hazard.

Siliceous soils are those that are particularly high in content of quartz, or silica (SiO_2), a very hard mineral that is very abrasive to moving parts of aircraft and vehicles. Quartz is the dominant mineral component of most of the soils of the world. It comprises nearly 100 percent of the clean sands in beach ridges and the dunes of sandy deserts. In most soils, however, quartz comprises less than 75 percent of the total soil; in some soils, quartz comprises a very small percentage of the soil. The coarser soil particles—the sands and silts—consist almost entirely of quartz.

For purposes of this study, siliceous soils are those composed mostly of sand particles. In general, sand particles occur in the deserts and semi-deserts of arid regions and on beaches, beach ridges, and narrow coastal plains throughout the world. Sand particles in soils of other textural classes are also likely to be composed of quartz; but, because the proportion of sand in the soil is smaller, these soils are not classified as siliceous. Thus, sandy loams, loams, sand clay loams, and sandy clays contain appreciable proportions of sand which have the same physical properties as the sands in the soils classified as siliceous.

Vitreous soils are soils with a high content of volcanic glass. Like the siliceous soils, vitreous soils are abrasive to moving parts of aircraft and vehicles. Composition of the glass varies from place to place because of the variety of conditions under which glass can be formed. However, the glass commonly is hard; and individual particles, sand and silt in size, having sharp, angular edges. These soils are associated with areas of relatively recent volcanic activity most extensively distributed in a broad arc around the

Pacific Ocean and less extensively, in the vicinity of the Caribbean and Mediterranean Seas, the eastern Atlantic Ocean, and in eastern Africa.

Soils containing titanium minerals are also a source of abrasion. The content of this oxide in such soils is commonly less than 1.5 percent, but in localized areas it can exceed 3.0 percent. Such is the case with the friable tropical clay soils of Hawaii, the titanium oxide content of which ranges from about 6.0 to as much as 25.0 percent in the surface 6 inches of soil. However, these soils are characteristic of less than 4 percent of the land area of the Hawaiian Islands; the very heavy concentrations of titanium oxide between 15 and 25 percent by content are confined to 0.8 percent of the land areas. Concentrations of titanium oxide are likely to occur in soils of basic volcanic materials on the islands of Oceania and in analagous areas elsewhere throughout the world. Presently, the specific locations are not known and individual areas are likely to be inextensive and highly local in occurrence; therefore, they are not shown on the map.

Saline soils are a source of soluble salts that are extremely conducive to the corrosion of metal parts. Saline soils contain concentrations of chlorides and sulphates of calcium, sodium, magnesium, and potassium. These salts accumulate as white crystals on or close to the surface as the capillary water which carries them to the surface evaporates. In extreme conditions, these crystalline salts form a continuous crust on the surface of the soil. Commonly, saline soils occur in flats and depressions; individual areas are not extensive. Saline soils are distributed unevenly in those parts of the world having little or no precipitation.

Potentially highly acid soils are also a source of corrosion. The high degree of acidity is caused by the oxidation of sulfides which accumulate in perennially saturated soils. If such soils are drained and subsequently exposed to the atmosphere, the sulfides become oxidized. Solution of these oxides produces sulfuric acid, and strongly acid soils result. It is only in the oxidized state as sulfates that the concentrations of sulfides in these soils are effective in producing these extremely acid conditions. These potentially highly acid soils, along with the efflorescence of crystalline sulfur which in some locations can be seen on the surface of spoil banks along drainage ditches and canals, are known to occur in the Bangkok plain in Thailand, the Irrawaddy delta in Burma, the Mekong delta of South Vietnam, along the coast of the Benelux countries in western Europe, on the Atlantic and Gulf coasts of the United States, and on the low-lying periphery of the islands of Oceania.

Although concentrations of iron and aluminum in soils could be of critical concern to this study, relatively high contents of oxides of these elements do not generally occur in surface soils. Commonly, the proportion of these oxides in the surface 6 inches of soil is less than about 5 percent in the case of iron oxide and less than about 12 percent in the case of aluminum oxide. However, in some parts of the world, high contents of oxides of iron and aluminum are characteristic of subsoils at depths below the 6-inch surface level. Where the subsoil has been exposed by erosion or grading or the soil has been otherwise disturbed by mixing, these oxides probably will be present in the surface 6 inches of the resulting soil material. Commonly, the oxides are in colloidal form (very fine particles). Because of their very small size, the oxide particles exhibit a marked tendency to cling to various surfaces. Soils that are underlain by materials having a high content of oxides of iron and aluminum are the widely distributed red and yellow silty and clayey soils in semi-tropical and tropical regions and the friable red clays of the humid tropics.

Soils consisting of, or having an appreciable proportion of, montmorillonitic clay are a source of fine dust. Montmorillonitic clay particles commonly are smaller than other clay particles and are characterized by swelling in water. In general, particle sizes range from 0.01 to 1.0 micrometer (0.00001 to 0.001 millimeter) in diameter. The particles are highly cohesive and are not readily detached from adjoining soil particles; however, when dry and subjected to repeated traffic or otherwise disturbed, the particles tend to form a fine dust readily moved by air currents. Montmorillonitic clays have a strong negative charge that manifests itself in a tendency of the particles to cling to metallic surfaces. Areas in which montmorillonitic clays can be expected are generally located in the tropics and semi-tropics—mainly, India, east central Australia, west central Africa, and southern United States.

III. CONCLUSIONS

5. **Conclusions.** The maps contained in the rear pocket of this report constitute the principal product of the research conducted. As such, they can be viewed as a graphic summary of the study findings. These are represented by the delineations shown—one or more for each of the soil types or subtypes mapped. Basically, each type has a potential for the generation of dust either by (1) agitation of the soil by natural causes such as wind or (2) agitation induced by mechanical means such as vehicular traffic or the downwash of air created by helicopter rotors in operation.

In using the maps, the reader should be aware of certain design features of the maps that limit their utility. Because of the small scale, the maps show only the general or prevailing characteristics of each division mapped. It can be expected, therefore, that each sector delineated will contain elements of alien soil types or subtypes that are too small in areal extent to be shown at the scale used. Should there be a requirement for detail of this order, it would be necessary to remodel the study along lines that would include development of a more sophisticated soil classification and the selection of a base map of sufficient scale to accommodate a detailed analysis. Basic to an expanded analysis, also, is the matter of data sufficiency. To properly support a

detailed global analysis of soils, data of the specialized types needed should be available in sufficient number and in comparable detail to adequately characterize all land surfaces wherever they are positioned on the map. This is a most difficult objective to attain if, indeed, it be attainable at all.

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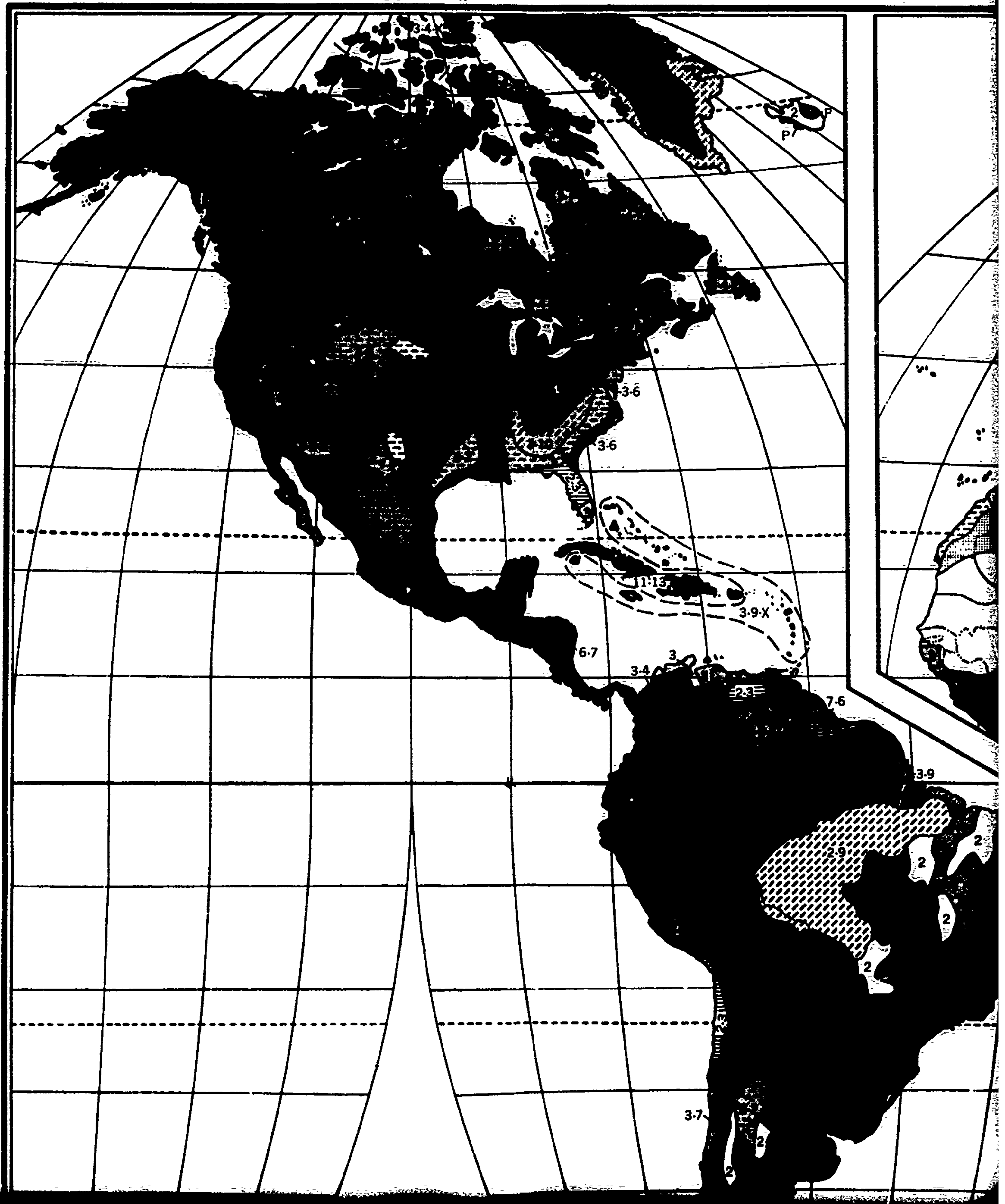
PREPARED FOR SPECIAL REPORT ETL-SR-72-1 IN ACCORDANCE WITH SPECIFICATIONS PRESCRIBED BY THE GEOGRAPHIC SCIENCES LABORATORY, USAETL.

U. S. DEPARTMENT OF AGRICULTURE

SOILS:



2

SOILS: SURFACE TEXTURES

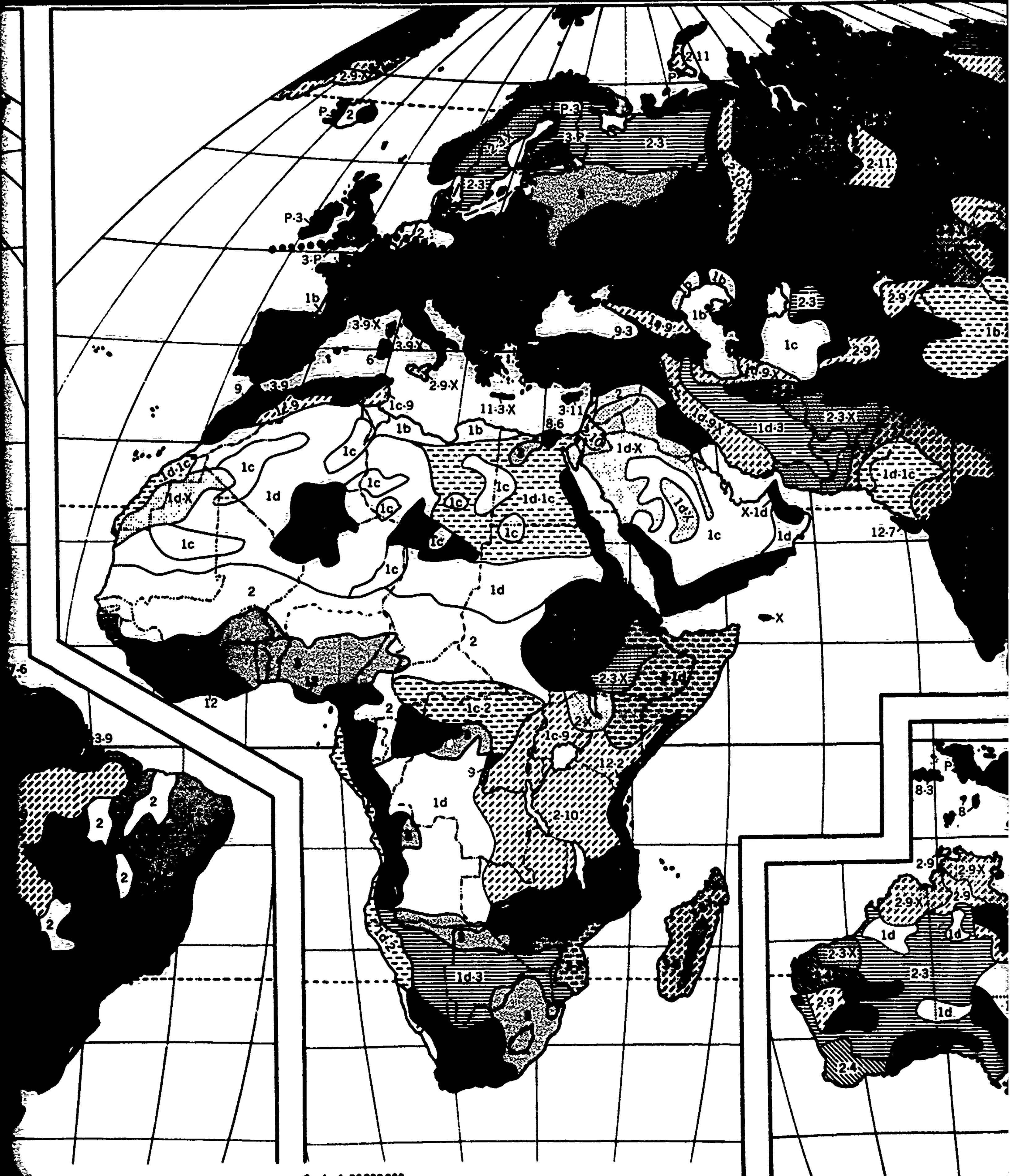


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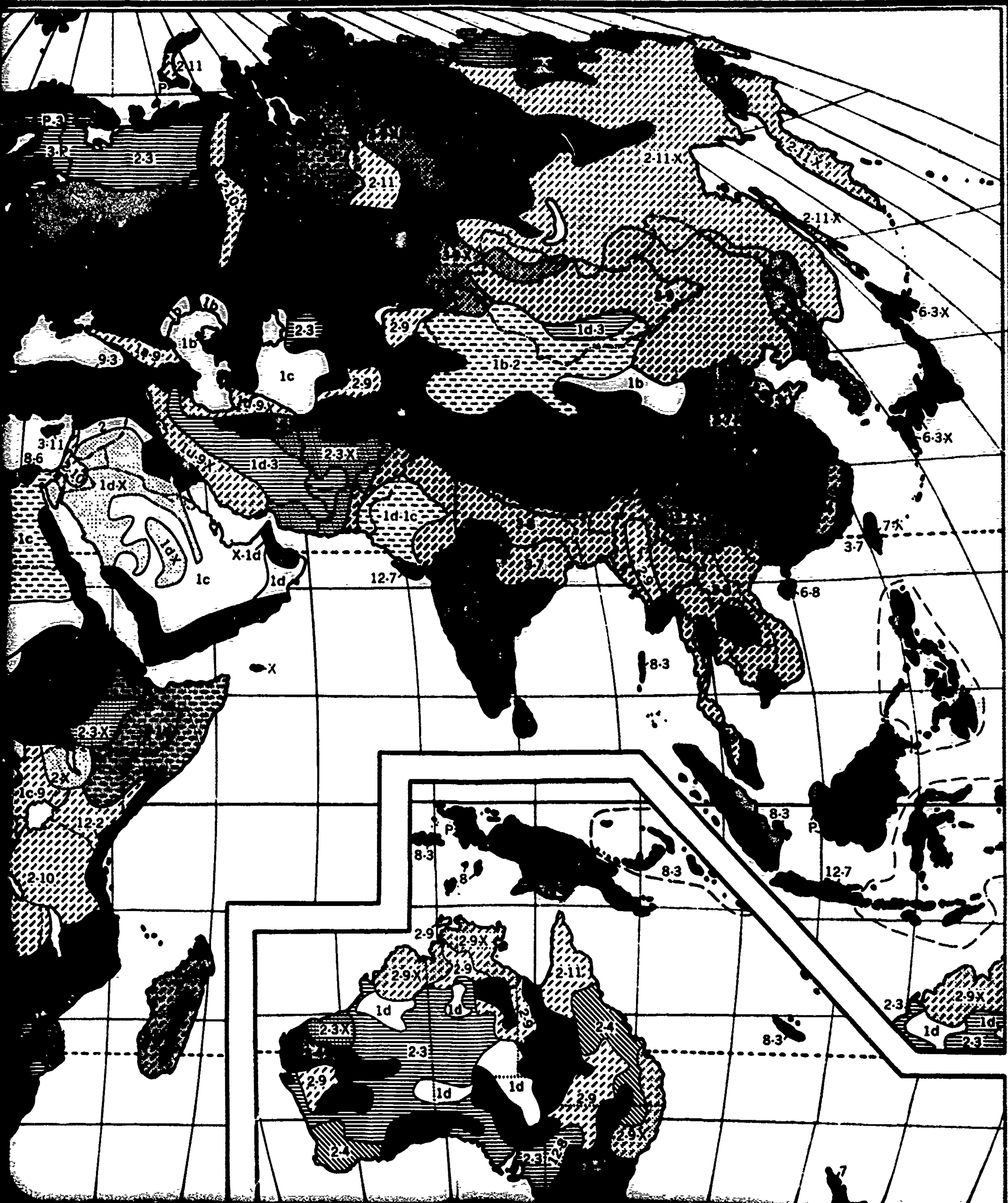
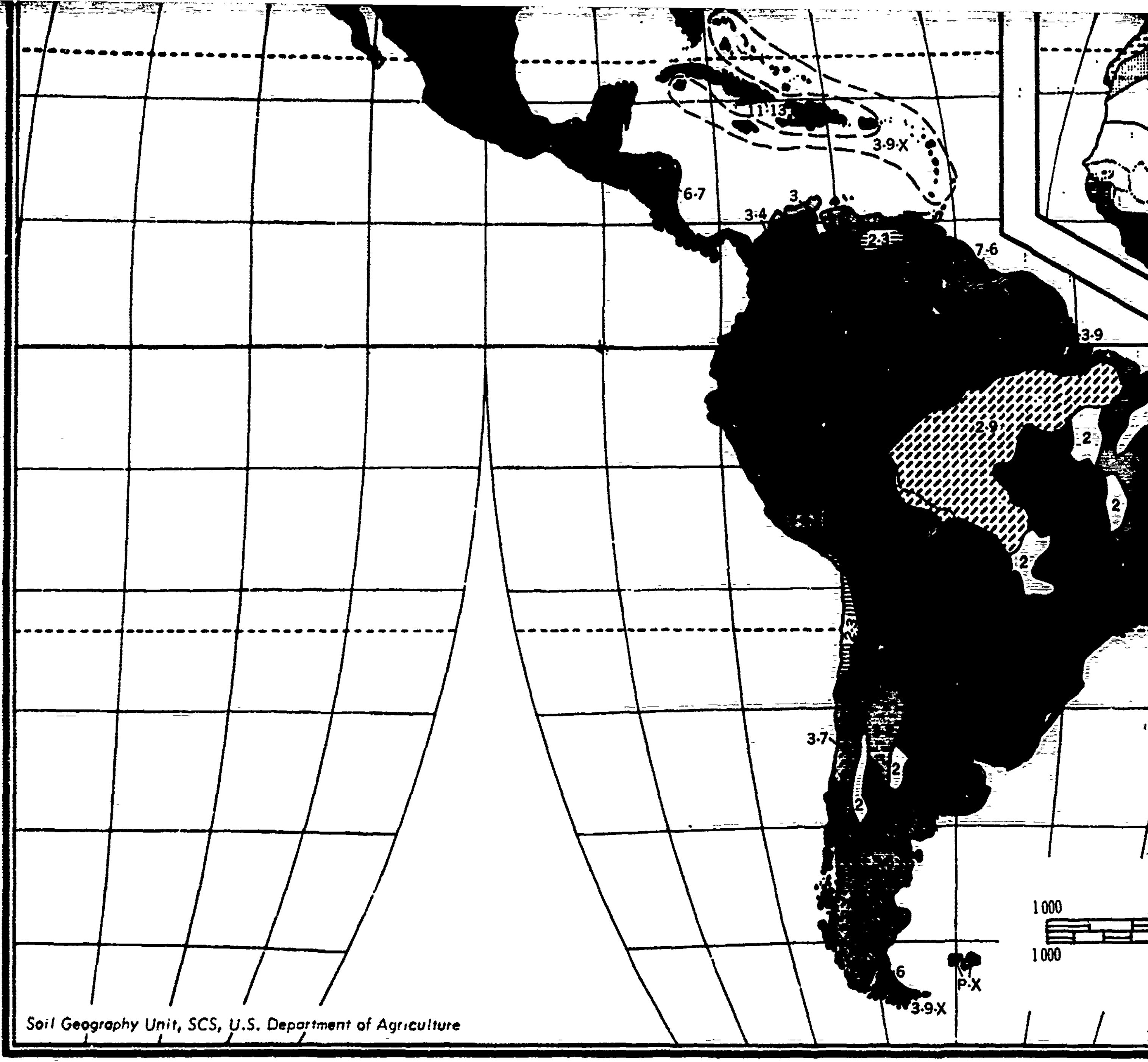
PLATE I

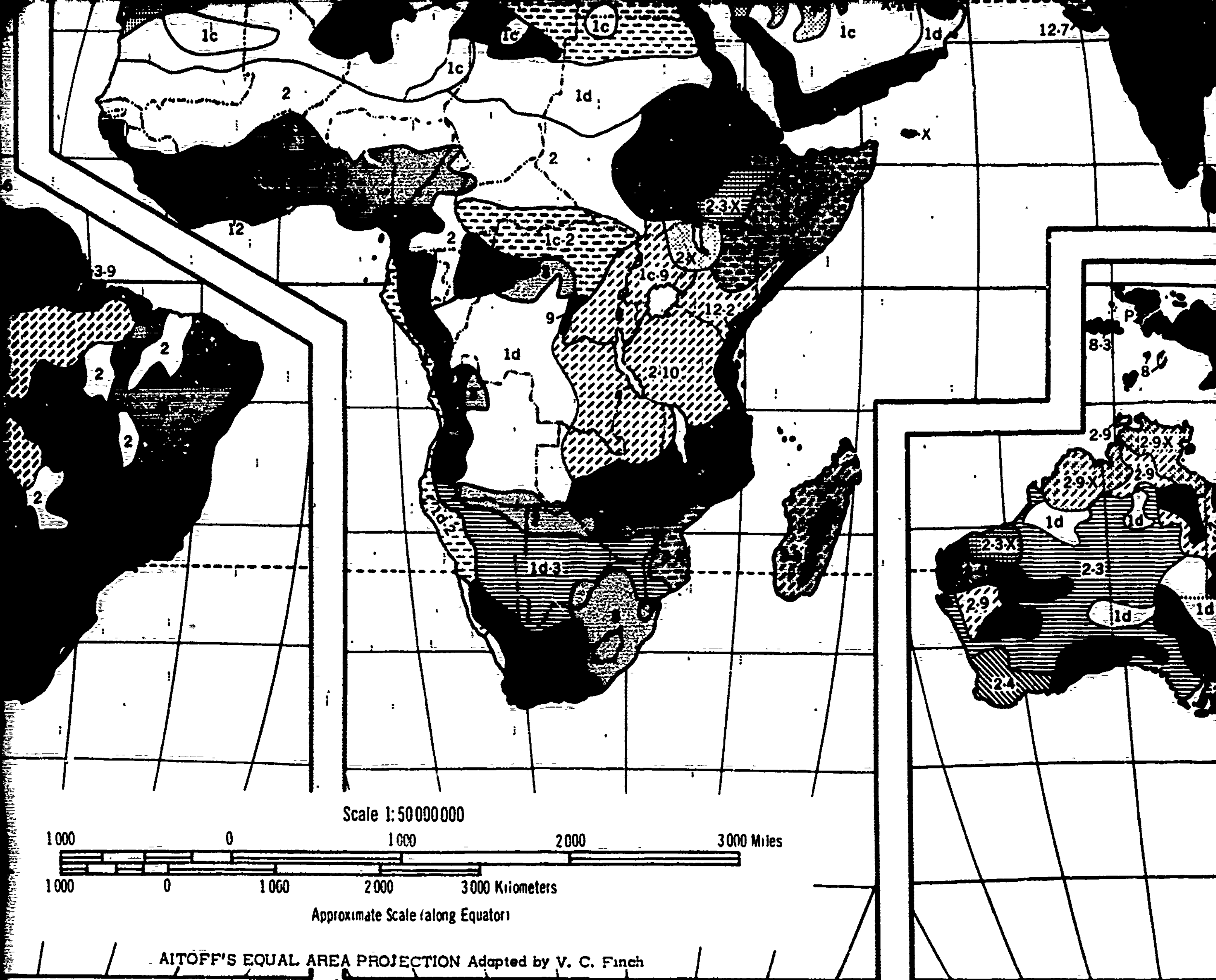
TURES

SOIL CONSERVATION SERVICE





MAP SYMBOLS: DOMINANT SOIL	MAP SYMBOLS: SUBDOMINANT OR CODOMINANT SOIL	MAP SYMBOLS: NUMERICAL CODE*	TEXTURE CLASS	RANGE IN COMPOSITION**(PERCENT): SAND	SILT	CLAY
		1	Sand	85 – 100	0 – 15	0 – 10
		1a	Coarse sand	25% or more of sand particles 2000 – 500μ, less than 50% any other single sand size.		
		1b	Medium sand	25% or more of sand particles 2000 – 250μ, less than 50% 250 – 50μ.		
		1c	Fine sand	50% or more of sand particles 250 – 50μ.		
		1d	Undifferentiated	Size of sand particles unclassified.		
		2	Loamy sand	70 – 85	0 – 30	0 – 15
		3	Sandy loam	52 – 85	0 – 52	0 – 20
		4	Loam	23 – 52	28 – 50	7 – 27
		5	Silt	0 – 20	80 –100	0 – 12
		6	Silt loam	0 – 50	50 – 80	0 – 28



(PERCENT)
CLAY
0 – 10
2000 – 500μ, less
nd size.
2000 – 250μ, less
50 – 50μ.
ied.
0 – 15
0 – 20
7 – 27
0 – 12
0 – 28

TEXTURE OF SURFACE SOILS

MAP SYMBOLS			TEXTURE CLASS	RANGE IN COMPOSITION** (PERCENT)		
DOMINANT SOIL	SUBDOMINANT OR CODOMINANT SOIL	NUMERICAL CODE*		SAND	SILT	CLAY
		7	Silty clay loam	0 – 20	40 – 72	27 – 40
		8	Silty clay	0 – 20	40 – 60	40 – 60
		9	Sandy clay loam	45 – 80	0 – 28	20 – 35
		10	Sandy clay	45 – 65	0 – 20	35 – 55
		11	Clay loam	20 – 45	15 – 52	27 – 40
		12	Clay	0 – 45	0 – 40	40 – 100
		13	Clay (tropical)	friable clays of humid tropical areas; clay particles held in very stable silt-size aggregates.		
		P	Organic material	---	---	---
		X	Areas generally devoid of soil	---	---	---
●●●●●●●●●●●			Approximate southern limit of the area in which sand and silt particles are predominantly angular.			

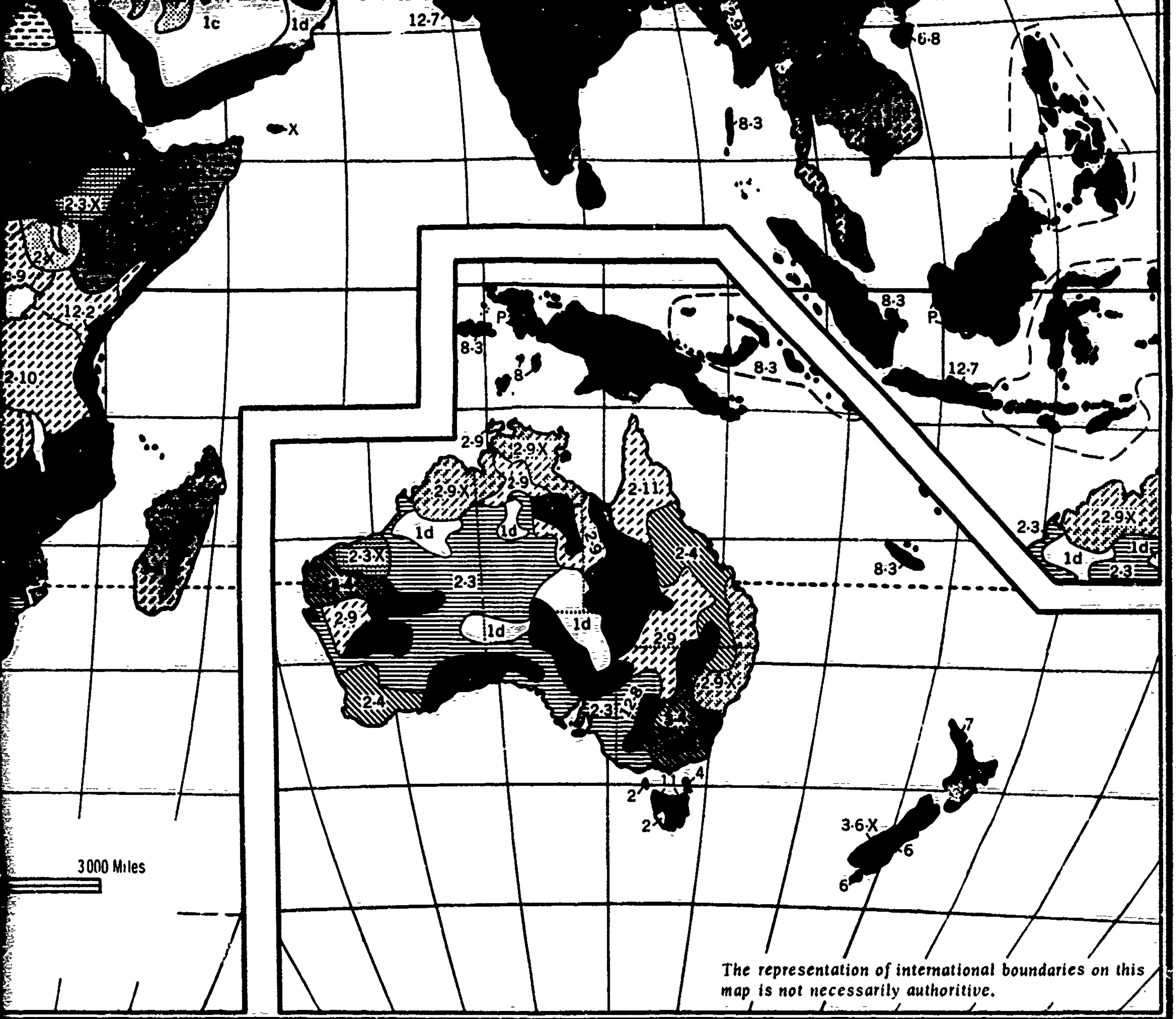
PARTICLE SIZE

Particle	Range in
	microns (μ)
Sand	2000 – 50
Silt	50 – 2
Clay	less than 2

*Compound symbols, such as
or conditions are extensive;
equal or somewhat lesser ext
tensive.

**Adapted from Soil Survey
U. S. Department of Agricul

5



GE IN COMPOSITION**(PERCENT)

D	SILT	CLAY
20	40 – 72	27 – 40
20	40 – 60	40 – 60
80	0 – 28	20 – 35
65	0 – 20	35 – 55
45	15 – 52	27 – 40
45	0 – 40	40 – 100

ays of humid tropical areas; clay parti-
in very stable silt-size aggregates.

	---	---
	---	---

he area in which sand and silt
angular.

PARTICLE SIZE RANGE

Particle	Range in Diameter	
	microns (μ)	millimeters (mm)
Sand	2000 – 50	2.0 – 0.05
Silt	50 – 2	0.05 – 0.002
Clay	less than 2	less than 0.002

(The term "micron" (μ) has the same meaning as the currently used term "micrometer" (μm).)

*Compound symbols, such as 6-9 or 2-10-X, mean that two or three textures or conditions are extensive; the second named texture or condition is of equal or somewhat lesser extent than the first, and the third is least extensive.

**Adapted from Soil Survey Manual, U. S. D. A. Handbook No. 18. U. S. Department of Agriculture. 1951.

December 1971

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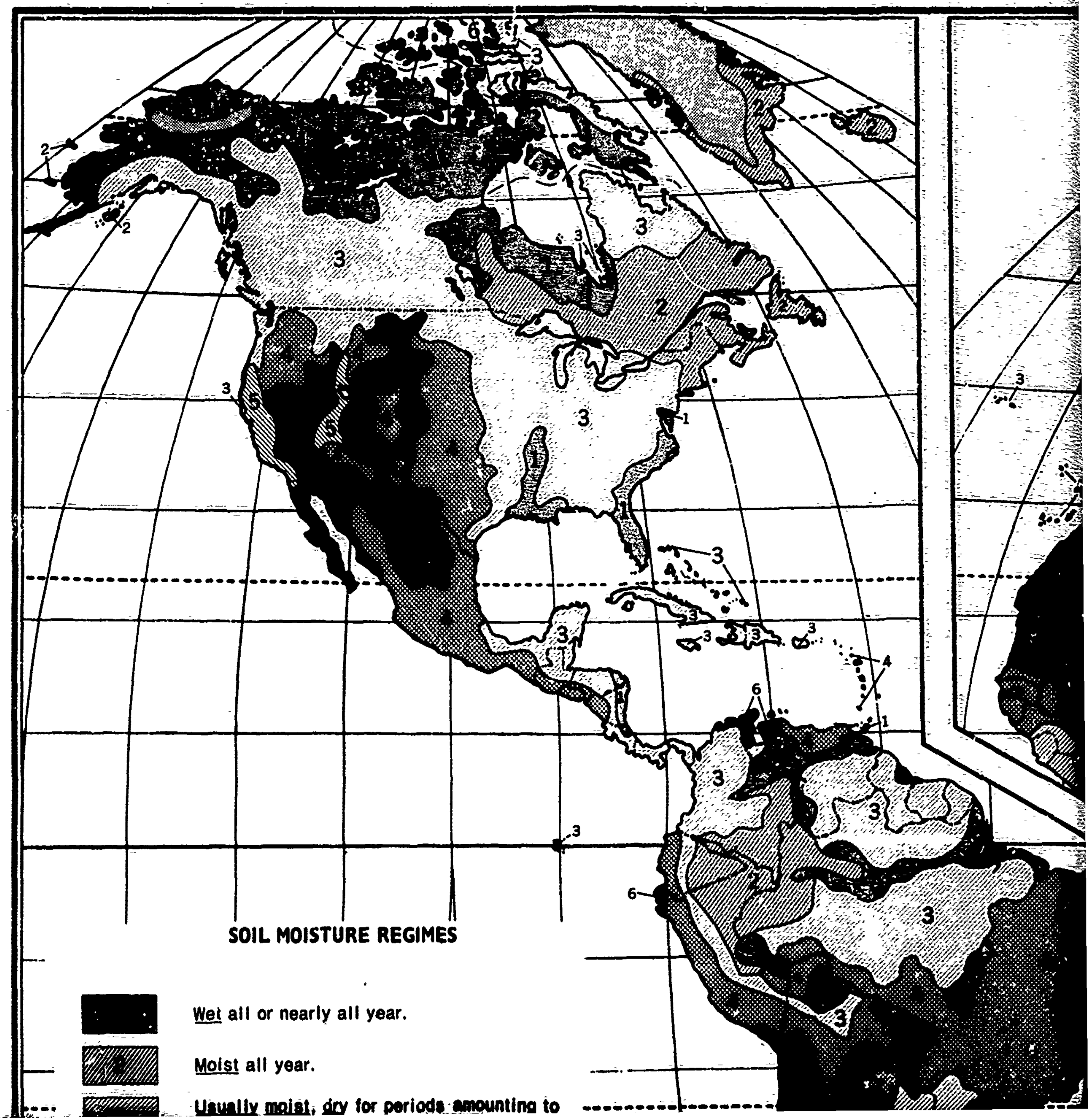
PREPARED FOR SPECIAL REPORT ETL-SR-72-1 IN ACCORDANCE WITH SPECIFICATIONS PRESCRIBED BY THE GEOGRAPHIC SCIENCES LABORATORY, USA ETL.

U. S. DEPARTMENT OF AGRICULTURE

SOILS:



2

MOISTURE REGIMES

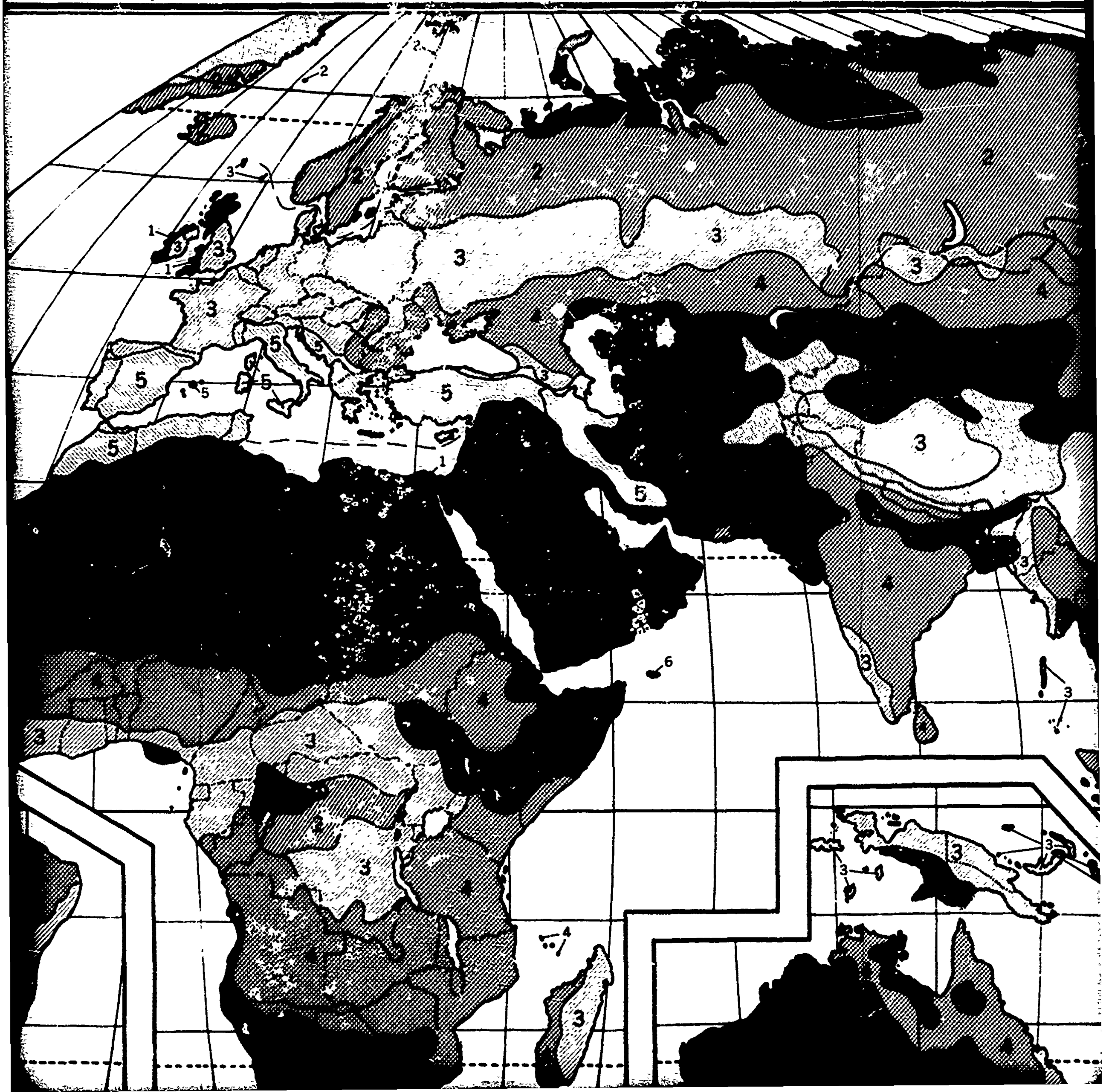
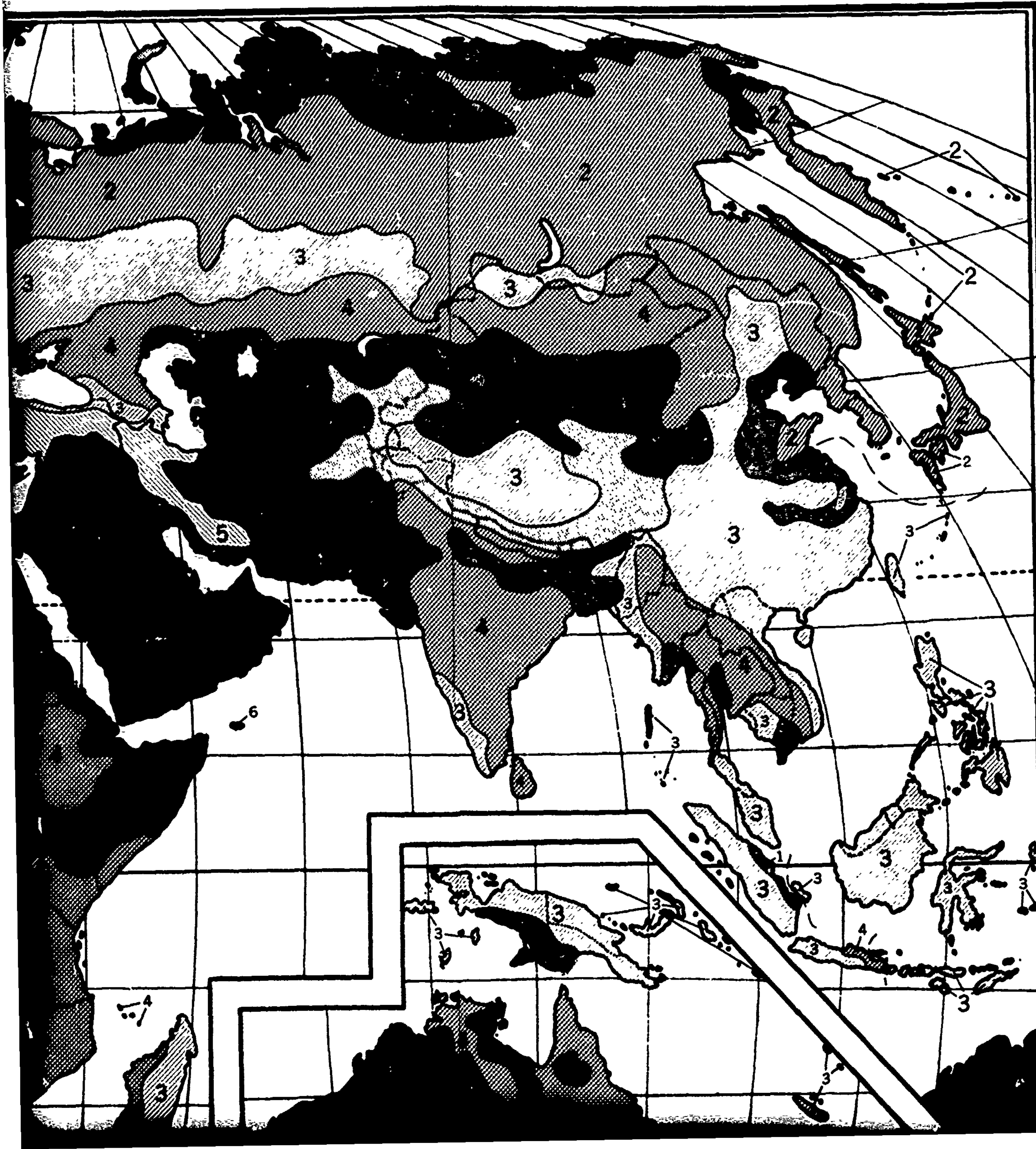
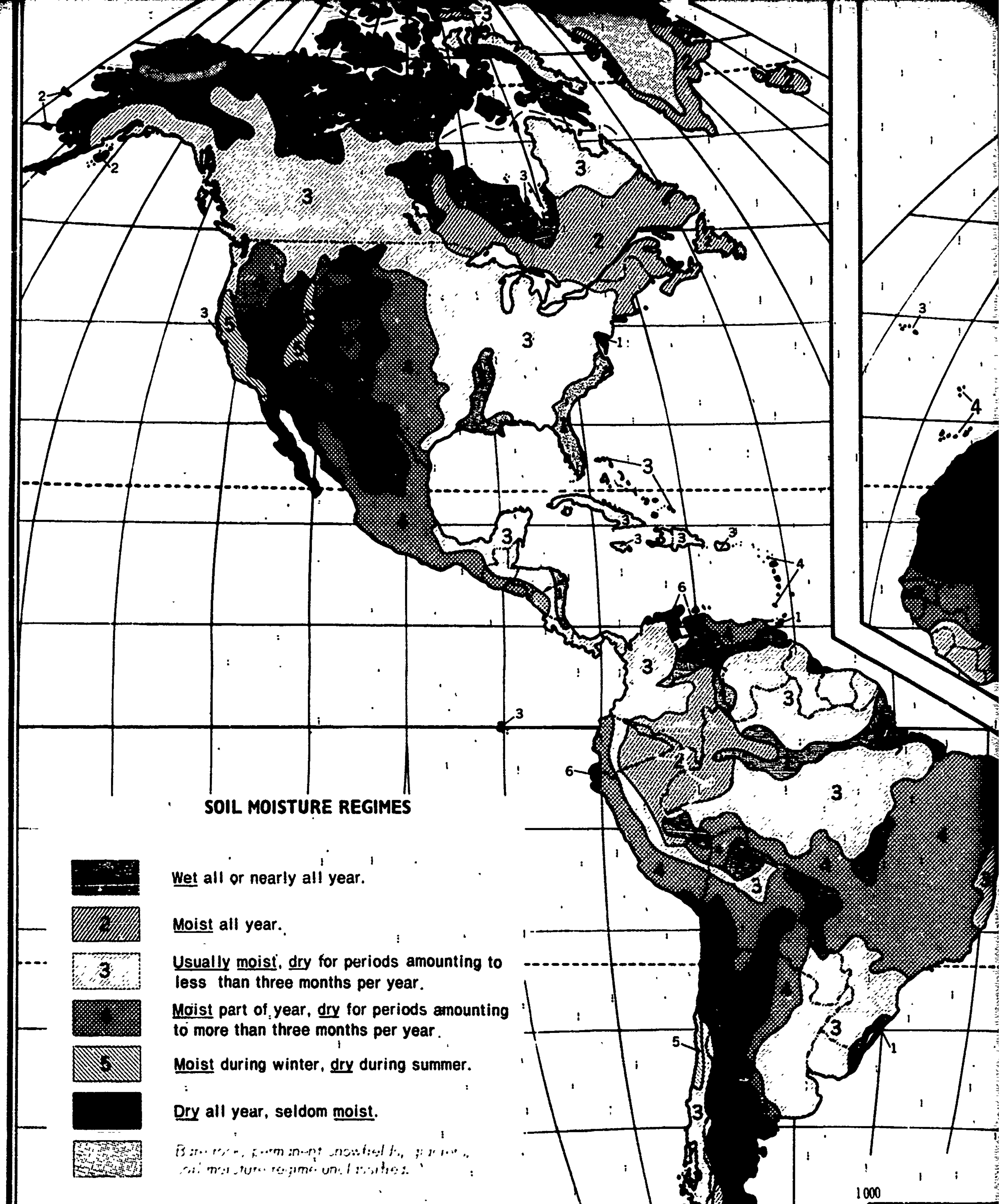


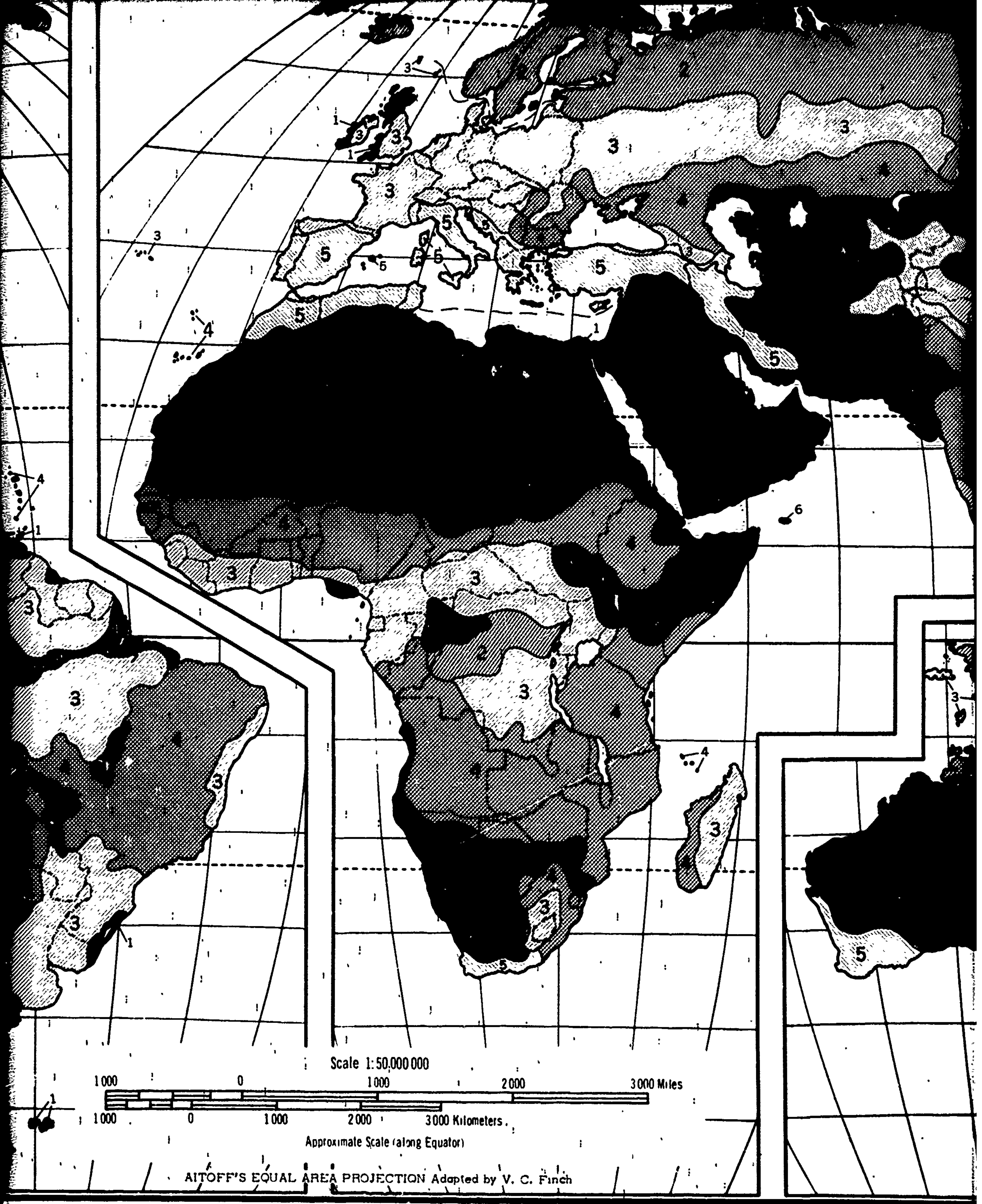
PLATE II

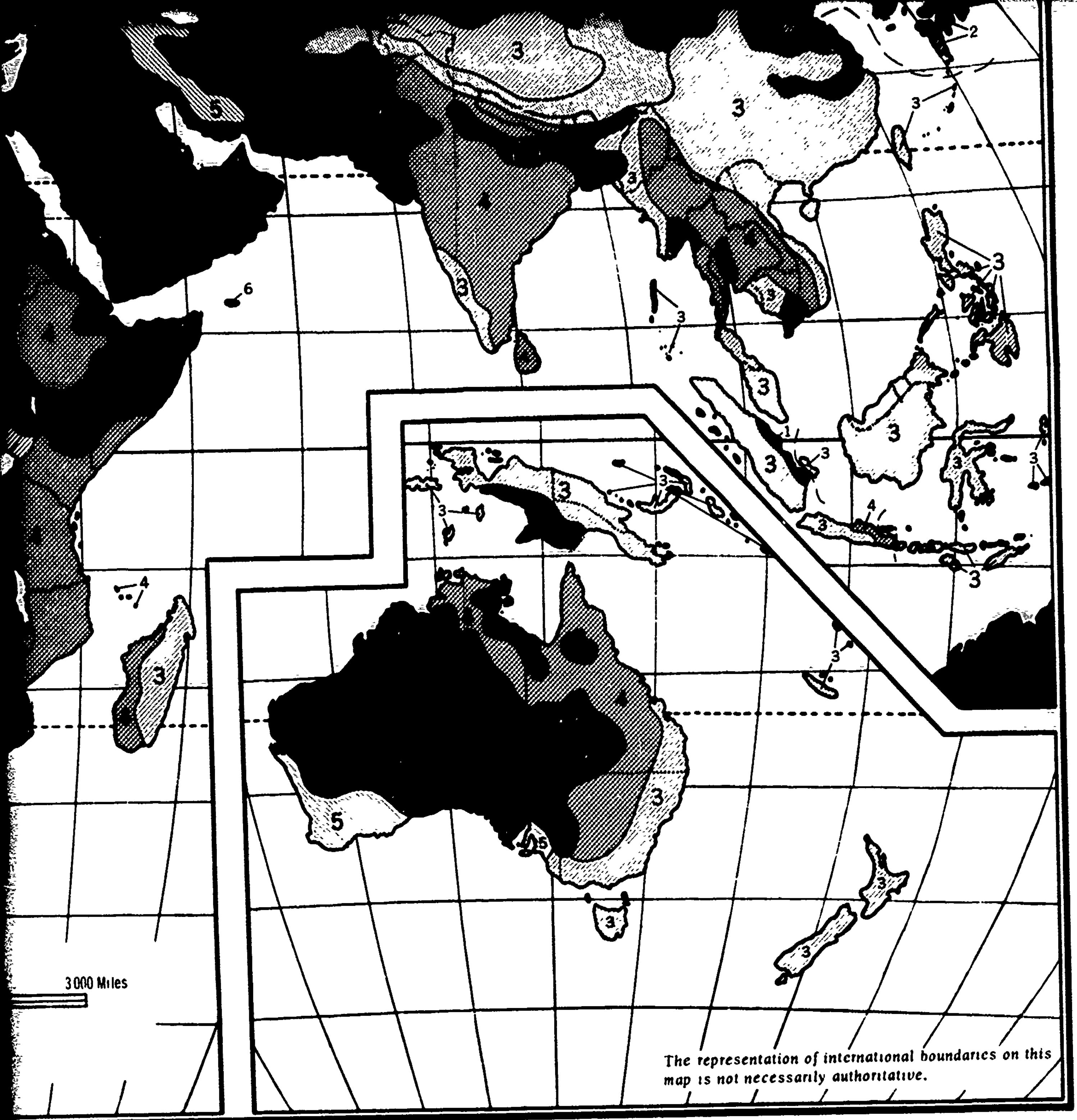
MES

SOIL CONSERVATION SERVICE




SOIL MOISTURE REGIMES
Wet all or nearly all year.
Moist all year.
Usually moist, dry for periods amounting to less than three months per year.
Moist part of year, dry for periods amounting to more than three months per year.
Moist during winter, dry during summer.
Dry all year, seldom moist.
Soil Geography Unit, SCS, U.S. Department of Agriculture
AITOFF


Scale 1:50,000,000
1000 0 1000 2000 3000 Miles
1000 0 1000 2000 3000 Kilometers
Approximate Scale (along Equator)
AITOFF'S EQUAL AREA PROJECTION Adapted by V. C. Finch



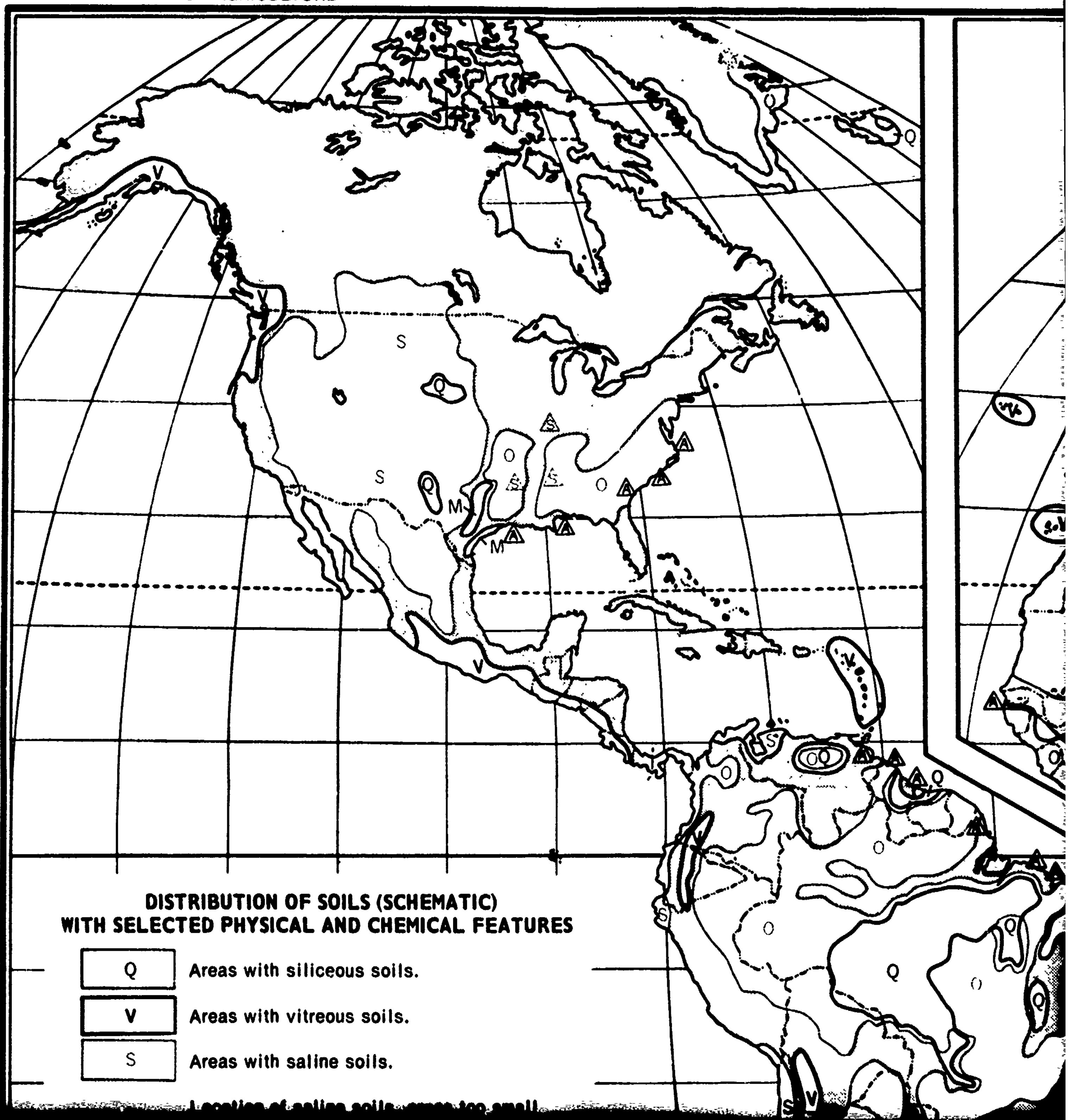
6

December 1971
USDA SCS HYATTSVILLE MD 1-71

PREPARED FOR SPECIAL REPORT ETL-SR-72-1 IN ACCORDANCE WITH SPECIFICATIONS PRESCRIBED BY THE GEOGRAPHIC SCIENCES LABORATORY, USAETL.

DISTRIBU
With Selecte

U. S. DEPARTMENT OF AGRICULTURE



2

DISTRIBUTION OF SOILS (SCHEMATIC)
ith Selected Physical and Chemical Features

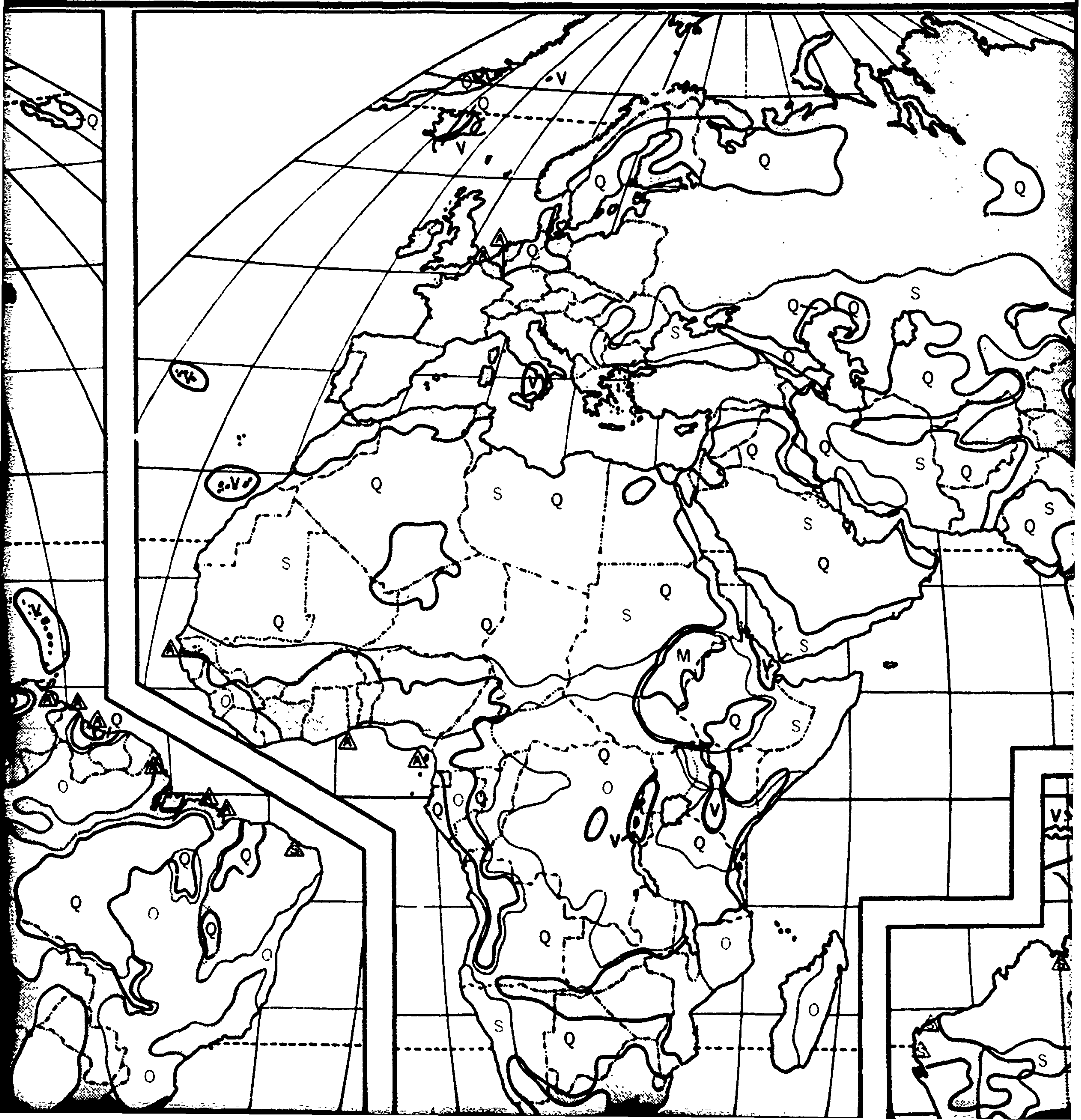
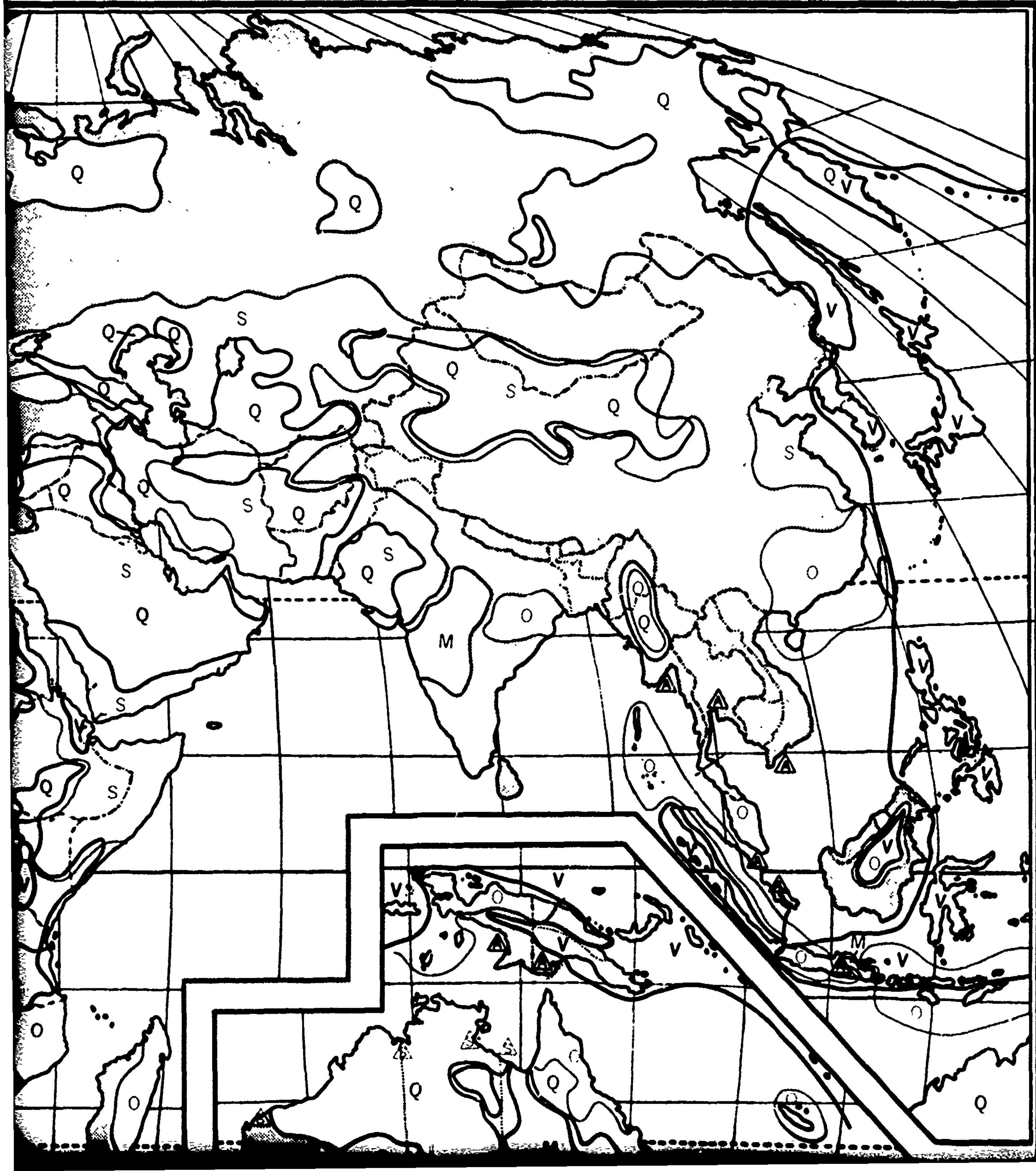


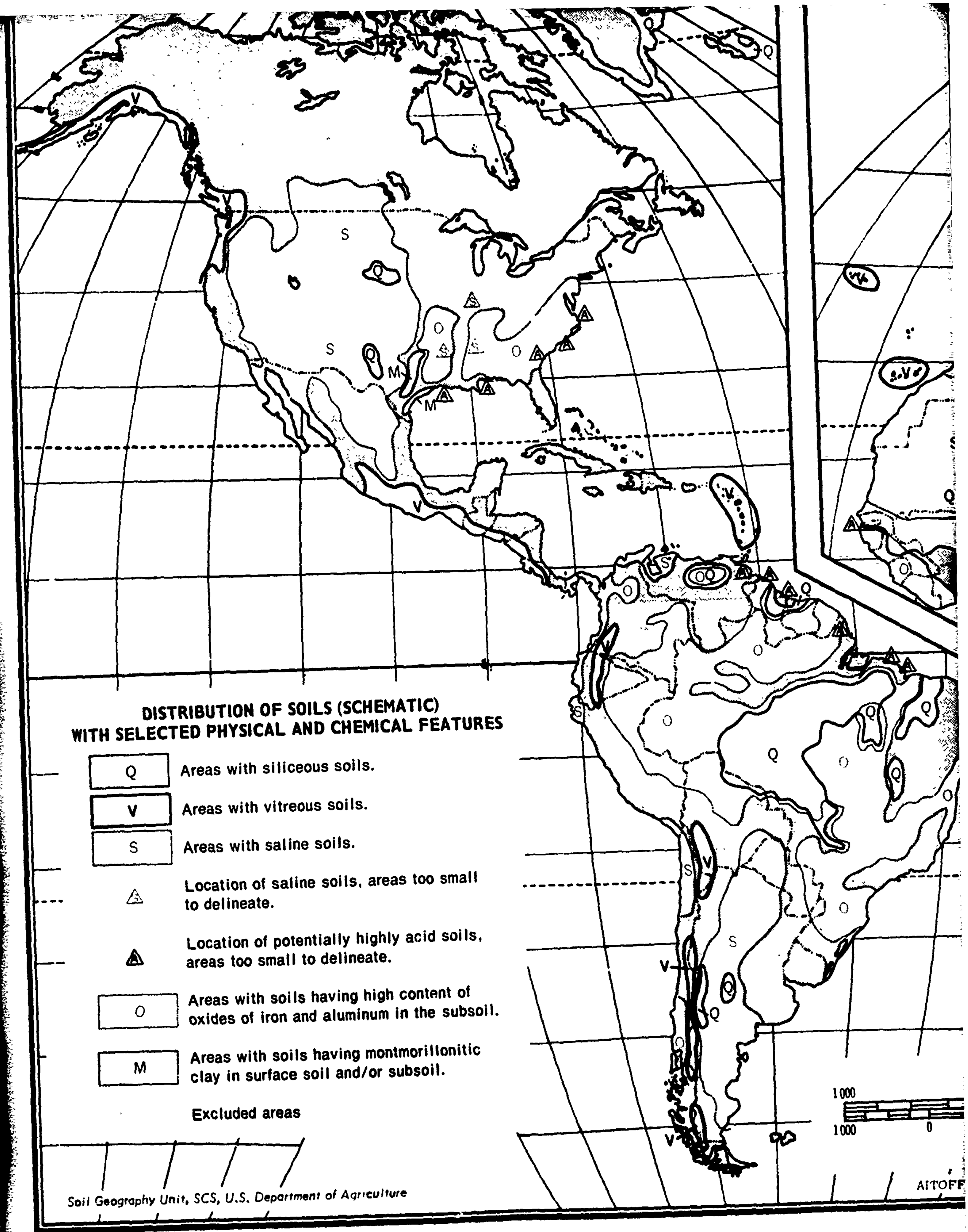
PLATE III

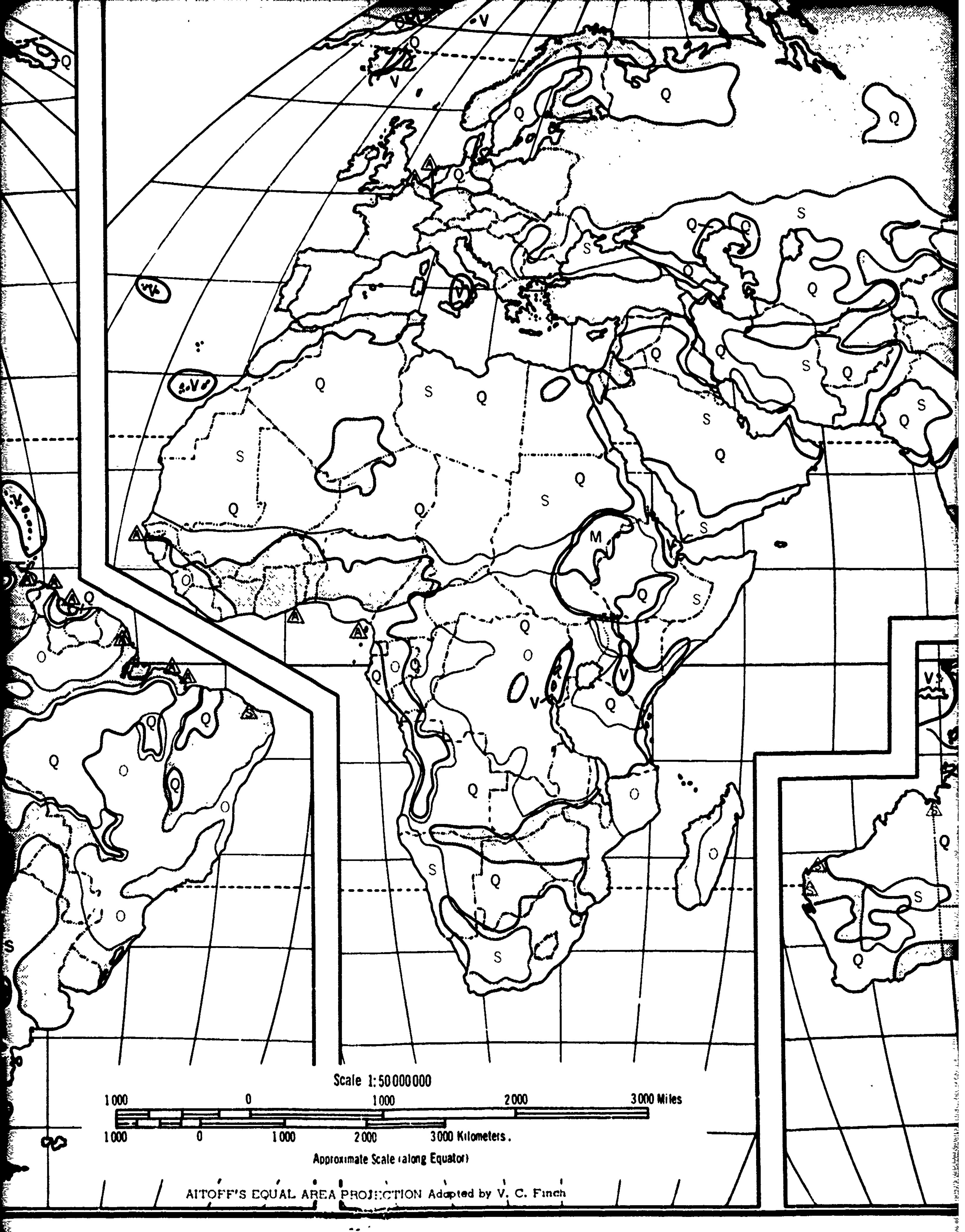
EMATIC)
al Features

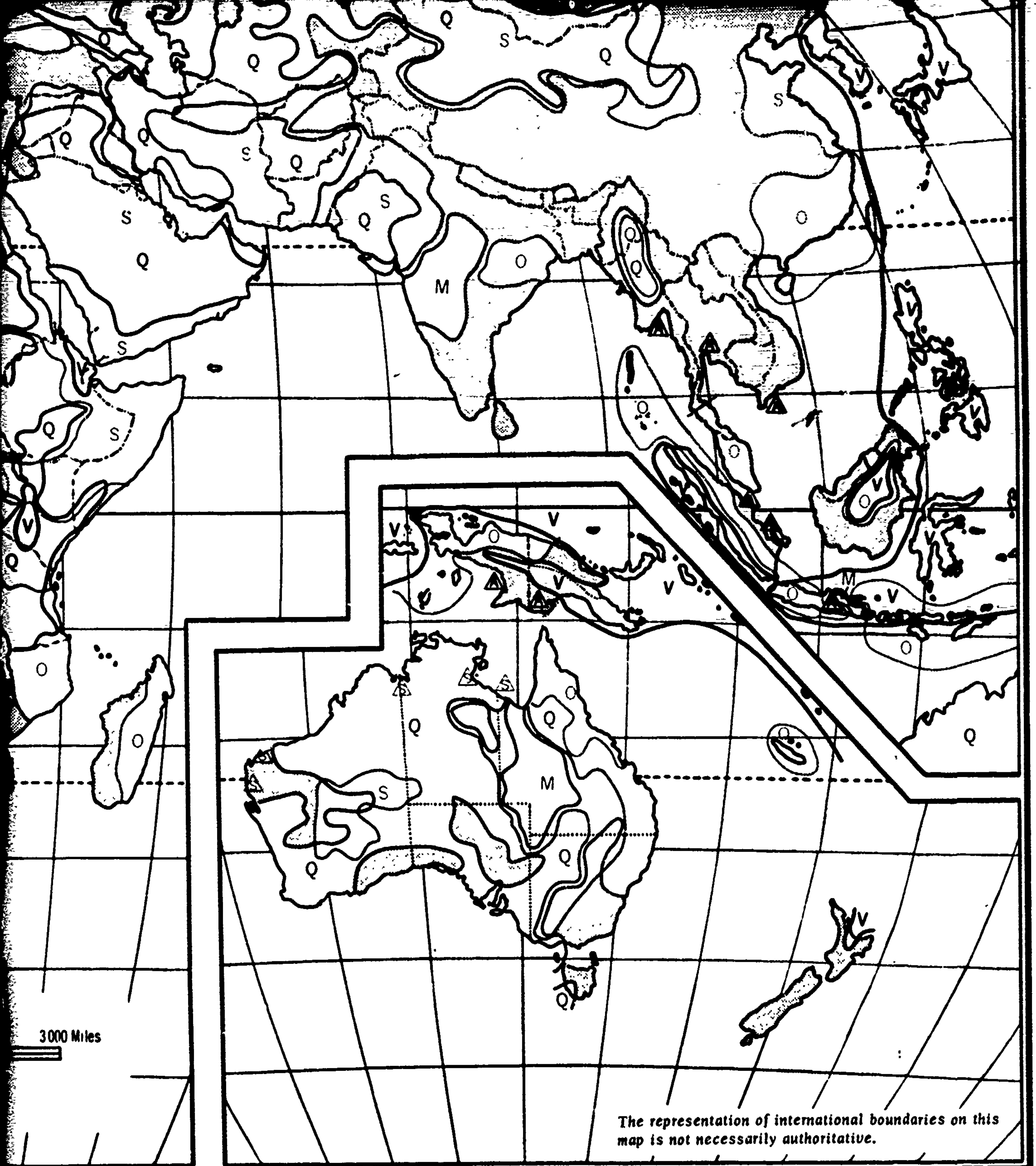
3

SOIL CONSERVATION SERVICE




DISTRIBUTION OF SOILS (SCHEMATIC)
WITH SELECTED PHYSICAL AND CHEMICAL FEATURES
Q Areas with siliceous soils.
V Areas with vitreous soils.
S Areas with saline soils.
Location of saline soils, areas too small to delineate.
Location of potentially highly acid soils, areas too small to delineate.
O Areas with soils having high content of oxides of iron and aluminum in the subsoil.
M Areas with soils having montmorillonitic clay in surface soil and/or subsoil.
Excluded areas
Soil Geography Unit, SCS, U.S. Department of Agriculture
1000
1000
0
AITOFF


Scale 1:50 000 000
1 000 0 1 000 2 000 3 000 Miles
1 000 0 1 000 2 000 3 000 Kilometers.
Approximate Scale (along Equator)
AITOFF'S EQUAL AREA PROJECTION Adapted by V. C. Finch



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