U.S. Geological Survey

Field Library

P. O. Box 4217

Albuquerque, New Mexico 87106

TEI-865

WORLD DISTRIBUTION OF SOIL, ROCK, AND VEGETATION

By Jerald M. Goldberg, F. Raymond Fosberg, Marie-Helene Sachet,
and Allen Reimer

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

metadc502054

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WORLD DISTRIBUTION OF
SOIL, ROCK, AND VEGETATION*

By

Jerald M. Goldberg
F. Raymond Fosberg and Marie-Helene Sachet
Geological Survey
and
Allen Reimer
Soil Conservation Service, U. S. Department of Agriculture

June 30, 1965

Report TEI-865

This report is preliminary
and has not been edited for
conformity with Geological
Survey format and nomenclature.

*Prepared on behalf of the U. S. Atomic Energy Commission.

USGS - TEI-865

WORLD DISTRIBUTION OF SOIL, ROCK, AND VEGETATION

<u>Distribution</u>	<u>No. of copies</u>
U. S. Atomic Energy Commission:	
Division of Technical Information Extension, Oak Ridge	2
George P. Dix, Division of Space Nuclear Systems	100
Headquarters Library	1
John Colp, Sandia Corporation	10
Nevada Operations Office	2
Walter G. Belter, Division of Reactor Development and Technology	15
U. S. Geological Survey, Geologic Division:	
Assistant Chief Geologist for Engineering Geology	1
Chief Geologist	1
Military Geology Branch	50
Special Projects Branch	2
U. S. Geological Survey, Water Resources Division:	
Area Hydrologist, Arlington	1
Area Hydrologist, Denver	1
Area Hydrologist, Menlo Park	1
Area Hydrologist, St. Louis	1
Chief Hydrologist	1
District Geologist, GW, Albuquerque	1
General Hydrology Branch (A. Clebsch)	10
General Hydrology Branch, Denver (W. E. Hale)	2
Las Vegas Subdistrict Office	2
U. S. Soil Conservation Service:	
World Soil Geography Unit	50
	<u>254</u>

CONTENTS

	<u>Page</u>
Introduction	1
Soil	2
Rock	5
Permafrost, perennial snow and ice, and inland water	6
Agricultural land use	33
Selected references	37

TABLES

	<u>Page</u>
Table 1 Composition of the land surface of the earth	7
Table 2 Areas of the world covered by permafrost or perennial snow and ice	9
Table 3a Soil - Africa	10
Table 3b Rock - Africa	11
Table 4a Soil - Australasia	12
Table 4b Rock - Australasia	13
Table 5a Soil - Eurasia	14
Table 5b Rock - Eurasia	15
Table 6a Soil - North America	16
Table 6b Rock - North America	17
Table 7a Soil - South America	18
Table 7b Rock - South America	19
Table 8 Agricultural land use	35

ILLUSTRATIONS

	<u>Page</u>
Figure 1. Continental landmasses	3
Figure 2. Soil profile A	20
Figure 3. Soil profile B	21
Figure 4. Soil profile C	22
Figure 5. Soil profile D	23
Figure 6. Soil profile E	24
Figure 7. Soil profile F	25
Figure 8. Soil profile G	26
Figure 9. Soil profile H	27
Figure 10. Soil profile I	28
Figure 11. Soil profile J	29
Figure 12. Soil profile K	30
Figure 13. Soil profile L	31
Figure 14. Lithosols	32

INTRODUCTION

This report, prepared by the Military Geology Branch, U. S. Geological Survey in cooperation with the World Soil Geography Unit, U. S. Soil Conservation Service, summarizes work done on behalf of the Division of Reactor Development and Technology, U. S. Atomic Energy Commission. The objective of the study was to estimate the worldwide distribution of a few broad categories of naturally occurring materials found on the land surface of the earth. These materials may be catalogued or categorized in a variety of ways depending on the use to be made of such data. The data on soil and rock were developed for use in determining the effect of the surface on re-entry impact of space nuclear power devices; the data on agricultural use of the land were obtained for use in estimating the probability of introduction into the food chain of radioactive materials that might be released during re-entry burn up or impact.

The categories chosen for the first part of the study were as follows: soil; rock; continuous permafrost; perennial snow and ice; and, inland water. The first two categories are subdivided on the basis of kind of material and thickness or depth. The data for the earth as a whole are summarized in Table 1 and are presented for each continent in Table 2 for perennial snow and ice and permafrost and in Tables 4 through 7 for soil and rock. Additional information on the layering and physical properties of each kind of soil is given in Figures 2 through 14.

In the second part of the study, the land surface is subdivided according to intensity of agricultural practice. Data on 15 categories of cropland, grazing land, and natural vegetation are given for the world and for each continent in Table 8.

A geologist, a botanist, and an ecologist of the Geological Survey and a soil scientist of the Soil Conservation Service completed the study with a total effort of less than 10 man-months.

Information was drawn mostly from files of the Military Geology Branch and the World Soil Geography Unit. Maps showing distribution of the required categories, or of units which could be interpreted in these terms, were examined under a grid. The grid squares occupied by the categories or their subdivisions were counted for each country to determine the percentage distribution and square miles were derived from the percentages. More than 80 percent of the land surface was treated in this way, and the percentage figures derived for part of a continent were assumed to be valid for the remainder. Similarly, total area for the world was obtained by adding the area for each continent; these figures were then converted to percentages rounded off to the nearest tenth.

The question of accuracy of the figures is complex because better information was available for some countries than for others, and reliability is not everywhere uniform for soil, rock, and land use. The figures were derived from maps that varied greatly in reliability and that ranged in scale from about 1:700,000 to 1:7,000,000. These maps were prepared during the last 15 years for a classified program and were based on the best sources available at the time. Such sources, however, ranged from maps prepared in the field at scales larger than 1:100,000 to highly generalized office compilations at scales smaller than 1:1,000,000.

For the purpose of this report, the land area of the earth is taken to be 57,262,000 square miles (Seltzer, 1962). Some authorities assume a figure as large as 58,000,000 square miles, the difference resulting mainly from the variation in the size reported for Antarctica, which ranges from 5,000,000 to 6,000,000 square miles. The figure of 5,500,000 used here represents a consensus of various sources. Other differences result from the difficulty of determining which islands various authorities have included in the total land area of a specific continent; for example, the numerous islands lying between Asia and Australia. The continental divisions used are outlined in Figure 1.

SOIL

Soil in this study is considered to be the natural unconsolidated material overlying consolidated rock. It occurs as a continuum over most of the land surface. In some places the soil has been formed in place by disintegration and decomposition of rocks and reflects some of the characteristics of the underlying parent rocks. Differential weathering of the rocks, however, may induce marked differences in soil characteristics, particularly total thickness. In many more places, the soil has been reworked and transported by water, wind, or ice. Such action has resulted in an intricate mosaic or patchwork of many kinds of soil, for the most part subtly grading from one to another. There exists an almost infinite number of "kinds of soil," which not only differs laterally but with depth as well.

Despite their great diversity, soils have features that provide a basis for their classification and permit the depiction of local and regional patterns of occurrence. For example, soils consisting of eolian silts (loess) are uniform over wide areas, although total thickness and drainage may vary from place to place depending primarily on topographic position.

In this report 12 kinds of soil or soil assemblages have been selected as representative of the most common soils. These have been classified according to the Unified Soil Classification System (U. S. Army Engineer, 1953) and a soil profile diagram is depicted for each (figs. 2-13). These soil profiles depict layers of soil as they would occur in a vertical cut or section. The diagrams, although not drawn to scale, are intended to assist in visualizing the arrangement, the vertical sequence, and the range in thickness of layers of the various soils of an assemblage. The soil profile diagram in this study represent soils that are extensive; diagrams of many less extensive soils have not been included. Each soil profile diagram is a composite or a synthesis of soils of many areas.

More attention was paid to soil at or close to the surface than to the soils at considerable depth. This bias was introduced for two reasons: (1) the near-surface material was considered more significant for impact, and (2) the source information was generally better.

The Unified Soil Classification System has not been applied to soils where bedrock is commonly within 2 feet of the surface. These areas are designated by the pedological term "Lithosols," which connotes shallow and commonly stony soils (fig. 14). Neither have the soils been differentiated in areas where there is continuous permafrost, perennial snow and ice, or inland water bodies.

Soil assemblages apparently occupying less than about 1 percent of the land surface of the earth were not identified. However, special mention should be made of soils developed on volcanic ash and pumice because the bulk density of such soils is only about one-half that of other mineral soils. These light soils are common in New Zealand, Japan, Indonesia, Alaska, and the South American Andes.

ROCK

As indicated in the discussion of soil, rock is here distinguished from soils on the basis of degree of consolidation. A loose sand is soil; a sandstone is rock. Intermediate material exhibiting slight consolidation is generally regarded as soil if it is readily disaggregated by hand. Material requiring tools to break up or work is commonly regarded as rock. There is no generally recognized quantitative test and there has certainly been a considerable range of subjective judgment employed by the many different compilers of the maps used to prepare this report. The same can be said of the distinction made between hard rock and soft rock. Although most rock mapped as hard has relatively high compressive strength and specific gravity, mapping has rarely if ever been based on laboratory tests of these properties. This is because the primary purpose of nearly all geologic mapping has been to elucidate relationships of stratigraphy, structure, and petrology rather than engineering properties.

Rock has been divided into categories based on depth of soil cover as well as on physical aspects (see table 1). In areas where the rock is covered by soil more than 20 feet thick, only the soil has been considered. In those areas where rock is at or within 2 feet of the surface, only the rock has been subdivided. In the intermediate situation where the soil cover ranges from 2 to 20 feet thick, both soil and rock have been subdivided. The three categories of rock are as follows:

1. **HARD:** Dense, massive rocks, with specific gravities commonly ranging from 2.65 to greater than 3.0. Porosities tend to be low, commonly less than 5%; compressive strength is commonly 25,000 psi (pounds per square inch) or greater (Krynine and Judd, 1957). This category is composed primarily of igneous rocks, most commonly granite, gabbro, basalt, and rhyolite. It may include metamorphic rocks such as quartzite, gneiss, dolomite, and marble where they were estimated to have met the foregoing criteria.
2. **HARD AND SOFT:** Thin- to thick-layered, hard rock interbedded or otherwise closely associated with softer rock. Hard rocks are predominant but may be highly fractured or jointed. Specific gravity, porosity, and compressive strength of the hard rocks in this category vary widely, whereas the physical properties of the soft rocks are quite similar to those of category 3. This category generally includes metamorphic rocks such as gneiss, schist, serpentine, and slate as well as sedimentary rocks, mainly conglomerate, limestone, sandstone, shale, and tuff.
3. **SOFT:** Friable rock, commonly bedded, which may vary from coarse to fine grained with the coarse-grained rocks generally softer than the fine-grained ones. Rocks of this category tend to have low specific gravities commonly ranging from 2.35 to 2.70. Porosities are varied but may be quite high, some in excess of 20%; compressive strength is generally less than 25,000 psi. The rocks may display

extensive fractures, joints, or cavities. This category is most likely to include sedimentary rocks, mainly limestone, sandstone, shale, and locally gypsum, and some metamorphic rocks, mainly schist.

PERMAFROST, PERENNIAL SNOW AND ICE, AND INLAND WATER

In addition to the foregoing soil and rock groupings, areal extent of continuous permafrost, perennial snow and ice, and inland water are shown on the accompanying tables. All areas of perennial ice formed from the recrystallization of snow or other forms of precipitation are included. Although in some instances this ice has extended itself to form shelves over the sea, it has originated and lies primarily on land. Sea ice, including the very large areas of perennial polar sea ice, are excluded as not belonging to the land area even though its effect on re-entry impact is no doubt similar to that of some of the land ice. A more exhaustive study would probably lead to a subdivision of land ice and snow into two categories or more of penetrability and of seasonal variation in these. In Greenland where snow and ice cover more than 80 percent of the total land area, the average thickness is approximately 5,000 feet and the maximum measured thickness is about 11,000 feet, in the south-central part of the country (Flint, 1957). In Antarctica more than 95 percent of the continent is covered by snow and ice, which in several areas is more than 10,000 feet thick and throughout more than 75 percent of its coverage has a thickness exceeding 6,500 feet (Bentley and others, 1964). In this report no attempt has been made to determine the nature or condition of the soil or rock beneath the ice.

Permafrost is defined as perennially frozen soil or rock, occurring wherever the temperature remains below 0°C for several years, whether or not the material is actually consolidated by ice. The figures shown in Tables 1-7 for the extent of permafrost exclude those areas where there is perennial snow or ice cover. For the purpose of this report, only the zone of continuous permafrost, in contrast to the zones of sporadic and discontinuous permafrost, has been included in the permafrost category. Nevertheless, even small isolated bodies of permafrost would have the same effect at a point of impact as the continuous type. This effect may be appreciable in soil actually consolidated by ice but would probably be negligible in subzero but "dry" rock. The general range of thickness of permafrost in the continuous zone is 800 to 1,200 feet in northern Alaska and 1,000 to 1,500 feet in northern Siberia (Black, 1954). It is generally considered that permafrost under the ice caps of Antarctica, Greenland, and elsewhere is several thousand feet thick.

Inland water includes only those perennial bodies of water that are completely within the confines of the various continents, such as seas and lakes that have no direct communication with the sea. For example, the Caspian Sea comprises part of the inland water of Eurasia; the Black Sea is considered an arm of the Atlantic Ocean. Where there are great fluctuations in the shoreline of lakes, an attempt has been made to include only those areas continuously covered by water.

TABLE 1. COMPOSITION OF THE LAND SURFACE OF THE EARTH

ROCK			ALL CATEGORIES		SOIL	
	Percent	Square miles	Percent	Square miles	Percent	
I. Rock within 2 feet of surface			23.9	13,654,000	23.9	I. Soil less than 2 feet thick
1. Hard	8.6	4,880,000				Lithosols (see fig. 14)
2. Hard & soft - interbedded or undifferentiated	11.0	6,307,000				
3. Soft	4.3	2,467,000				
II. Rock with soil cover 2 to 20 feet thick			59.9			II. Soil more than 2 feet thick
1. Hard	10.6	6,066,000		4,074,000	7.1	A
2. Hard & soft - interbedded or undifferentiated	10.7	6,132,000		4,031,000	7.0	B
3. Soft	9.5	5,435,000		4,160,000	7.3	C
III. Soil cover at least 20 feet thick Rock undifferentiated	29.1	16,664,000		2,140,000	3.7	D
				4,377,000	7.7	E See individual soil pro-
				1,541,000	2.7	F files (figs. 2-13) for
				5,783,000	10.1	G detailed description of
				746,000	1.3	H each letter profile.
				1,309,000	2.3	I
				2,369,000	4.1	J
				2,282,000	4.0	K
			1,485,000	2.6	L	
Other materials and surface conditions						
Perennial snow and ice ^{1/}		6,219,000	10.8	6,219,000	All oceans with their connected seas, bays, and gulfs cover 139,350,000 square miles or 70.9 percent of the earth's surface. Land areas (with their inland waters) constitute 29.1 percent of the total surface of the globe.	
Continuous permafrost ^{2/}		2,327,000	4.1	2,327,000		
Inland water		765,000	1.3	765,000		
Total		57,262,000	100.0	57,262,000		

^{1/}Excluding sea ice

^{2/}Excluding areas covered by perennial snow and ice

TABLE 2. AREAS OF THE WORLD COVERED BY PERMAFROST
OR PERENNIAL SNOW AND ICE

(Square miles)

Continent	Continuous permafrost excluding areas cov- ered by perennial snow and ice ^{1/}	Perennial snow and ice with- in the zone of continuous permafrost	Perennial snow and ice out- side the zone of continuous permafrost	Total
Antarctica	175,000	5,325,000	---	<u>2/</u> 5,500,000
Eurasia	1,387,000	43,000	57,000	1,487,000
North America	765,000	755,000	30,000	1,550,000
South America	---	---	9,000	9,000
Other continents	---	---	---	---
Total	2,327,000	6,123,000	96,000	<u>3/</u> 8,546,000

1/ The zones of continuous permafrost include Antarctica and the sub-continental areas in the Northern Hemisphere circumscribing the Arctic Ocean. Discontinuous and sporadic permafrost in the sub-Arctic, as well as in the Himalayas, Andes, and elsewhere are not included.

2/ 100 percent of Antarctica.

3/ 14.9 percent of the land area of the earth.

NOTE: In the Arctic a thin surficial "active layer" thaws and remains unfrozen for a few months in summer; this material is generally saturated and very soft. In the ice-free areas of Antarctica the active layer is generally well drained and does not become soft.

TABLE 3a. SOIL - AFRICA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Representative soil profiles		
(Soils 2 feet or more thick)		
A	2,116,000	18.4
B	1,173,000	10.2
C	679,000	5.9
D	---	---
E	621,000	5.4
F	58,000	0.5
G	3,113,000	27.1
H	92,000	0.8
I	288,000	2.5
J	---	---
K	541,000	4.7
L	184,000	1.6
Lithosols (undifferentiated soils		
less than 2 feet thick)	2,555,000	22.2
Perennial snow and ice	---	---
Continuous permafrost	---	---
Inland water	80,000	0.7
Total	11,500,000	100.0

TABLE 3b. ROCK - AFRICA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Rock		
I. Rock within 2 feet of surface		
1. Hard	852,000	7.4
2. Hard & soft - interbedded or undifferentiated	1,174,000	10.2
3. Soft	529,000	4.6
		22.2
II. Rock with soil cover 2 to 20 feet thick		
1. Hard	1,437,000	12.5
2. Hard & soft - interbedded or undifferentiated	1,449,000	12.6
3. Soft	747,000	6.5
III. Soil cover at least 20 feet thick		
Rock undifferentiated	5,232,000	45.5
Perennial snow and ice	---	---
Continuous permafrost	---	---
Inland water	80,000	0.7
Total	11,500,000	100.0

This second largest continental landmass lies mostly within the tropics, and contains the largest percentage of deep unconsolidated material of any continent. The rock is deeply buried in such diverse areas as the deserts of northern Africa and the tropical rain forests of the Congo Basin. Areas of rock at or near the surface extend across northern Africa, including parts of the Sahara Desert, and throughout the highlands of east Africa.

TABLE 4a. SOIL - AUSTRALASIA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Representative soil profiles		
(Soils 2 feet or more thick)		
A	335,000	9.9
B	457,000	13.5
C	1,100,000	32.5
D	37,000	1.1
E	308,000	9.1
F	98,000	2.9
G	162,000	4.8
H	64,000	1.9
I	196,000	5.8
J	---	---
K	104,000	3.1
L	27,000	0.8
Lithosols (undifferentiated soils		
less than 2 feet thick)	494,000	14.6
Perennial snow and ice	---	---
Continuous permafrost	---	---
Inland water	---	---
Total	3,382,000	100.0

TABLE 4b. ROCK - AUSTRALASIA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Rock		
I. Rock within 2 feet of surface		
1. Hard	74,000	2.2
2. Hard & soft - interbedded or undifferentiated	319,000	9.4
3. Soft	101,000	3.0
		14.6
II. Rock with soil cover 2 to 20 feet thick		
1. Hard	214,000	6.3
2. Hard & soft - interbedded or undifferentiated	632,000	18.7
3. Soft	607,000	18.0
III. Soil cover at least 20 feet thick Rock undifferentiated	1,435,000	42.4
Perennial snow and ice	---	---
Continuous permafrost	---	---
Inland water ^{1/}	---	---
Total	3,382,000	100.0

The smallest of the continents, Australasia, has no great mountain ranges. The mountains of New Guinea, although very rugged, are of relatively small extent. Within Australia the limited areas of shallow soil and exposed rock are primarily in the Great Dividing Range of Queensland and in northern Australia. The islands of New Zealand contain relatively large areas of rock at or near the surface. Vast expanses of deep unconsolidated material are found in all parts of Australasia except along the east coast of Australia and in New Zealand.

^{1/}No areal extent has been allocated to inland water. The majority of surface drainage in Australia is intermittent. The large lakes of the interior are usually dry, and the area covered by these lakes is included in Category III. The largest lake on New Zealand is less than 250 square miles in area. No data are available for the lakes of New Guinea.

TABLE 5a. SOIL - EURASIA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Representative soil profiles		
(Soils 2 feet or more thick)		
A	1,401,000	6.8
B	886,000	4.3
C	1,298,000	6.3
D	948,000	4.6
E	2,328,000	11.3
F	824,000	4.0
G	103,000	0.5
H	515,000	2.5
I	536,000	2.6
J	2,126,000	10.3
K	721,000	3.5
L	618,000	3.0
Lithosols (undifferentiated soils		
less than 2 feet thick)	6,509,000	31.6
Perennial snow and ice	100,000	0.5
Continuous permafrost	1,387,000	6.7
Inland water	300,000	1.5
Total	20,600,000	100.0

TABLE 5b. ROCK - EURASIA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Rock		
I. Rock within 2 feet of surface		
1. Hard	2,032,000	9.9
2. Hard & soft - interbedded or undifferentiated	3,273,000	15.9
3. Soft	1,204,000	5.8
		31.6
II. Rock with soil cover 2 to 20 feet thick		
1. Hard	2,145,000	10.4
2. Hard & soft - interbedded or undifferentiated	2,483,000	12.0
3. Soft	1,731,000	8.4
III. Soil cover at least 20 feet thick Rock undifferentiated	5,945,000	28.9
Perennial snow and ice	100,000	0.5
Continuous permafrost	1,387,000	6.7
Inland water	300,000	1.5
Total	20,600,000	100.0

The Eurasian landmass is by far the world's largest, comprising over one-third of the land area of the earth. Eurasia has very extensive areas of shallow soil with rock at or near the surface. These are found mainly in the Scandinavian Peninsula, the Mediterranean peninsulas, and the almost continuous chain of mountains and highlands of central Asia extending from Turkey through Iran, Afghanistan, and India, into Tibet. The continent also has huge expanses of deep unconsolidated material on the North European Plain extending eastward from the Low Countries and Germany into western Siberia. The enormous area of permafrost lies almost entirely in Siberia whereas perennial snow and ice are scattered throughout the mountainous regions of the continent.

TABLE 6a. SOIL - NORTH AMERICA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Representative soil profiles		
(Soils 2 feet or more thick)		
A	160,000	1.7
B	357,000	3.8
C	842,000	9.0
D	742,000	7.9
E	920,000	9.8
F	554,000	5.9
G	---	---
H	75,000	0.8
I	131,000	1.4
J	188,000	2.0
K	---	---
L	498,000	5.3
Lithosols (undifferentiated soils		
less than 2 feet thick)	3,023,000	32.2
Perennial snow and ice	785,000	8.4
Continuous permafrost	765,000	8.2
Inland water	350,000	3.6
Total	9,390,000	100.0

TABLE 6b. ROCK - NORTH AMERICA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Rock		
I. Rock within 2 feet of surface		
1. Hard	1,474,000	15.7
2. Hard & soft - interbedded or undifferentiated	1,061,000	11.3
3. Soft	488,000	5.2
		32.2
II. Rock with soil cover 2 to 20 feet thick		
1. Hard	920,000	9.8
2. Hard & soft - interbedded or undifferentiated	590,000	6.3
3. Soft	1,427,000	15.2
III. Soil cover at least 20 feet thick Rock undifferentiated	1,530,000	16.3
Perennial snow and ice	785,000	8.4
Continuous permafrost	765,000	8.2
Inland water	350,000	3.6
Total	9,390,000	100.0

This continent has the highest percentage of shallow soils and exposed rock found on any of the continental landmasses. The great cordillera covering much of Alaska and Central America and the western parts of Canada and the United States has huge expanses of rock at or very near the surface as does the Laurentian Upland of eastern Canada. The principal areas of deeply covered rock are along the Atlantic and Gulf coasts of the United States and in coastal Alaska, and there are numerous relatively small areas of deep alluvial soil in the Great Basin in and near Nevada. Over 85 percent of the perennial snow and ice of North America is in Greenland; the zone of continuous permafrost lies mostly in Canada and Alaska north of the Arctic Circle.

TABLE 7a. SOIL - SOUTH AMERICA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Representative soil profiles		
(Soils 2 feet or more thick)		
A	62,000	0.9
B	1,158,000	16.8
C	241,000	3.5
D	413,000	6.0
E	200,000	2.9
F	7,000	0.1
G	2,405,000	34.9
H	---	---
I	158,000	2.3
J	55,000	0.8
K	916,000	13.3
L	158,000	2.3
Lithosols (undifferentiated soils		
less than 2 feet thick)		
	1,073,000	15.6
Perennial snow and ice	9,000	0.1
Continuous permafrost	---	---
Inland water	35,000	0.5
Total	6,890,000	100.0

TABLE 7b. ROCK - SOUTH AMERICA

CATEGORY	AREAL EXTENT	
	Square miles	Percent
Rock		
I. Rock within 2 feet of surface		
1. Hard	448,000	6.5
2. Hard & soft interbedded or undifferentiated	480,000	7.0
3. Soft	145,000	2.1
		15.6
II. Rock with soil cover 2 to 20 feet thick		
1. Hard	1,350,000	19.6
2. Hard & soft - interbedded or undifferentiated	978,000	14.2
3. Soft	923,000	13.4
III. Soil cover at least 20 feet thick		
Rock undifferentiated	2,522,000	36.6
Perennial snow and ice	9,000	0.1
Continuous permafrost	---	---
Inland water	35,000	0.5
Total	6,890,000	100.0

The relatively low percentage of shallow soils and exposed rock occur mainly in the Andes and the highlands of Brazil. Intensive weathering in broad areas of wet tropical climate has reduced the area of exposed rock. The principal areas of deep soil are in the Amazon and Orinoco Basins, the Pampas, and in many of the intermontane basins of the Andes.

FIGURE 2. SOIL PROFILE A

Soils in dunes generally much more than 20 feet thick.

DISTRIBUTION

Extensive in western Australia (Great Australian Desert), Eurasia (Gobi, Great Arabian, and Thar Deserts), Africa (Sahara and Libyan Deserts), and in many other smaller areas including parts of southwestern United States.

REMARKS

Mainly sand dunes; consisting of loose, poorly graded sand. Dunes either active or stabilized. Silty sand mainly in interdune areas which are commonly gravelly or stony. Soils dry throughout year.

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	2,116,000	18.4
Australasia	335,000	9.9
Eurasia	1,401,000	6.8
North America	160,000	1.7
South America	62,000	0.9
Total	4,074,000	

Percent of land surface of the earth: 7.1

FIGURE 3. SOIL PROFILE B

DISTRIBUTION	REMARKS
Mainly on nearly level plains of western and northern Australia, in southern Africa (Kalahari Desert), in parts of central Europe, in the Gran Chaco area of South America, in southwestern United States, and on the Canadian Shield.	Chiefly silty sand; in many places on borderline to clayey sand. Soil firm; contains lenses or thin layers of finer textured soils. In Australia and on the Canadian Shield soils contain considerable amount of rock fragments or gravel. Soil generally dry most of year, except in Canada where commonly moist in summer and frozen in winter. Surfaces firm to hard except in southern Africa, where soil loose and porous.

12

AREAL EXTENT		
CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	1,173,000	10.2
Australasia	457,000	13.5
Eurasia	886,000	4.3
North America	357,000	3.8
South America	1,158,000	16.8
Total	4,031,000	

Percent of land surface of the earth: 7.0

FIGURE 4. SOIL PROFILE C

DISTRIBUTION

Covers wide expanses in arid and semiarid regions. Extensive in northern Africa (Sahara Desert), southern Africa (Kalahari Desert), Eurasia (Gobi Desert), western two-thirds of Australia, southwestern United States, and many other areas.

REMARKS

Brown, reddish-brown, or grayish soils consisting chiefly of sandy surficial materials overlying a highly calcareous, indurated layer at depths of about 2 to 4 feet; this layer locally exposed at surface. Gravelly or stony surfaces common. Soil generally dry throughout year. Surface drainage rapid and permeability moderate to high. Underlying coarse- and fine-grained soils highly varied vertically as well as laterally.

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	679,000	5.9
Australasia	1,100,000	32.5
Eurasia	1,298,000	6.3
North America	842,000	9.0
South America	241,000	3.5
Total	4,160,000	

Percent of land surface of the earth: 7.3

FIGURE 5. SOIL PROFILE D

DISTRIBUTION

Mantles plains chiefly in central United States, the Pampas of South America, and plains and hills in parts of central and eastern Europe; also extensive on central China uplands.

REMARKS

Soils consist of eolian silt (loess). Upper part of soil trends toward silty clay (CL); lower part of profile generally buff-colored calcareous silt. In cool climates upper 1 or 2 feet very dark-colored (high in organic matter). Soil generally moist and friable; has good internal drainage unless topographically low. Most areas originally grass covered; now most are cultivated.

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	---	---
Australasia	37,000	1.1
Eurasia	948,000	4.6
North America	742,000	7.9
South America	413,000	6.0
Total	2,140,000	

Percent of land surface of the earth: 3.7

FIGURE 6. SOIL PROFILE E

2

DISTRIBUTION

Mainly in regions with temperate or cool climate. Extensive on uplands and highlands of central Asia and south China; in eastern Australia, all parts of United States and Europe, on high plateau areas of Africa, and in many other land areas of the world.

REMARKS

Many residual soils with wide range of morphological features and behavior characteristics; in many areas probably mixed with windblown silt (loess). Clay content highest from about 2 feet to about 4 feet in depth. Clay fraction dominantly illite and montmorillonite; some kaolinite. Generally well drained on surface, but imperfect subsurface drainage. Soil moist most of year, but may be seasonally saturated or dry.

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	621,000	5.4
Australasia	308,000	9.1
Eurasia	2,328,000	11.3
North America	920,000	9.8
South America	200,000	2.9
Total	4,377,000	

Percent of land surface of the earth: 7.7

FIGURE 7. SOIL PROFILE F

Total soil thickness generally much more than 20 feet.

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	58,000	0.5
Australasia	98,000	2.9
Eurasia	824,000	4.0
North America	554,000	5.9
South America	7,000	0.1
Total	1,541,000	

Percent of land surface of the earth: 2.7

DISTRIBUTION

Covers flood plains and terraces along many of world's major rivers.

REMARKS

Soils consist mostly of water-transported materials. Surficial layer, particularly on higher lying terraces, may be of eolian origin (loess). Most soils are seasonally wet and very soft; many have high water table. Lower lying areas occasionally flooded.

FIGURE 8. SOIL PROFILE G

Silty sand (SM) or lateritic clay (MH).

Laterite layer; concretionary or slaglike; not present everywhere.

Silty sand (SM), clayey sand (SC), or lateritic clay (MH).

Lateritic clay dominant soil component.

Soil commonly very deeply weathered; much more than 20 feet thick.

DISTRIBUTION

REMARKS

Very extensive on tropical uplands. Occurs over wide area in west and central Africa and in tropical interior of South America.

Yellowish to reddish, thoroughly weathered, acid soils. Laterite layer varies from scattered concretions to massive, nodular, or slaglike material; locally "crusts" or laterite on surface. Clay fraction consists mainly of kaolinite and sesquioxides. Permeability and surface drainage generally good. Lateritic clay very friable. Soil predominantly moist.

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	3,113,000	27.1
Australasia	162,000	4.8
Eurasia	103,000	0.5
North America	---	---
South America	2,405,000	34.9
Total	5,783,000	

Percent of land surface of the earth: 10.1

FIGURE 9. SOIL PROFILE H

DISTRIBUTION

Occurs generally in fairly small, scattered areas. Covers most of Basutoland highlands and parts of Ethiopian plateau in Africa, scattered areas in southern United States and in Australia, and large area in west-central India.

REMARKS

Gray to black, mainly residual soils. High clay content--up to 70 percent. Clay fraction dominantly 2:1 expanding lattice type. When dry, soil hard and with vertical cracks. In cultivated areas, cloddy when plowed. Permeability low and surface drainage slow.

27

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	92,000	0.8
Australasia	64,000	1.9
Eurasia	515,000	2.5
North America	75,000	0.8
South America	---	---
Total	746,000	

Percent of land surface of the earth: 1.3

FIGURE 10. SOIL PROFILE I

DISTRIBUTION	REMARKS
Occurs mainly in broad topographic depressions, and on some alluvial lacustrine, and coastal plains. Extensive in the Sudan depression (the Sudd), probably the largest expanse of these soils in the world. Also extensive in the lower Mississippi and Amazon Valleys, the Deccan Plateau (India), the Bangkok plain (Thailand), and northern Australia.	Soils consist mainly of water-transported materials. Clays mostly montmorillonite. Soil shrinks and expands with alternate drying and wetting; surface hard and with deep cracks when thoroughly dry. Clay dense with slow permeability. Soil exhibits characteristics of internal wetness, such as gleying. Some soils saline, particularly in depressions and in arid and semiarid regions.

AREAL EXTENT		
CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	288,000	2.5
Australasia	196,000	5.8
Eurasia	536,000	2.6
North America	131,000	1.4
South America	158,000	2.3
Total	1,309,000	

Percent of land surface of the earth: 2.3

FIGURE 11. SOIL PROFILE J

Randomly distributed clayey gravel (GC), silty sand (SM), silt (ML), silty clay (CL), and plastic clay (CH). Not all present in all regions.

Silty sand and silty clay dominant soil components.

Soil generally 4 to 12 feet thick.

DISTRIBUTION

Extensive on tundra plains in northern Eurasia and in Canada.

REMARKS

Heterogeneous mixture of soils generally containing numerous rock fragments. Individual soils partly stratified and graded; generally wet or frozen.

29

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	---	---
Australasia	---	---
Eurasia	2,126,000	10.3
North America	188,000	2.0
South America	55,000	0.8
Total	2,369,000	

Percent of land surface of the earth: 4.1

FIGURE 12. SOIL PROFILE K

Silty gravel (GM), poorly graded sand (SP), silty sand (SM), clayey silt (ML), and silty clay (CL). Not all present in all regions; sequence and thickness of individual layers highly varied.

DISTRIBUTION

On alluvial flood plains; on terraces and fans in arid and semi-arid regions; and extensive in Amazon Basin. Common worldwide on coastal plains.

REMARKS

Very heterogeneous soil derived from water-transported materials. Soil in lower portion of profile commonly dense and compacted. On old terraces and fans in arid and semiarid regions, thin indurated layers of calcareous material (caliche) are often present at a depth of 2 to 3 feet. In tropical areas, especially in Amazon Basin, hard laterite (as in Soil Profile G) common. Permeability and surface drainage highly varied.

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	541,000	4.7
Australasia	104,000	3.1
Eurasia	721,000	3.5
North America	---	---
South America	916,000	13.3
Total	2,282,000	

Percent of land surface of the earth: 4.0

FIGURE 13. SOIL PROFILE I

DISTRIBUTION

Occurs in swamps and marshes of coastal lowlands and interior depressions throughout world. Extensive on tundra plains, especially in northern Canada and in Siberia. Also occurs much less extensively on some high plains and basins in mountainous areas.

REMARKS

Soils permanently waterlogged and consequently very soft. Underlying coarse- and fine-grained soils commonly stratified. On high plains, soils shallow and generally contain much rock debris. In tundra areas, soils gravelly; frozen for several months each year.

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	184,000	1.6
Australasia	27,000	0.8
Eurasia	618,000	3.0
North America	498,000	5.3
South America	158,000	2.3
Total	1,485,000	

Percent of land surface of the earth: 2.6

FIGURE 14. LITHOSOLS

Thin undifferentiated
soil; commonly stony;
less than 2 feet thick
nearly everywhere.

DISTRIBUTION

Occurs mainly in mountainous regions and other areas of steep slopes in all parts of the world; greatest areal extent in Eurasia and North America.

REMARKS

Many small intermontane basins and valleys included in this category. In some mountainous areas, especially in New Zealand, Japan, Indonesia, and South America, ash of varied composition mantles the slopes of active and inactive volcanoes.

32

AREAL EXTENT

CONTINENT	SQUARE MILES	PERCENT OF CONTINENT
Africa	2,555,000	22.2
Australasia	494,000	14.6
Eurasia	6,509,000	31.6
North America	3,023,000	32.2
South America	1,073,000	15.6
Total	13,654,000	

Percent of land surface of the earth: 23.9

AGRICULTURAL LAND USE

In this study estimates have been made of the percentage of the land surface covered by 15 categories of cropland, grazing land, and natural vegetation (table 8). The categories have been selected and grouped so as to emphasize the distribution of food crops and grazing land. Although much of our food comes from the sea, discussion of marine areas is beyond the scope of this report.

In addition to the 15 categories, areas of perennial snow and ice and inland water are accounted for. Areas of permafrost, however, are not considered separately as they are commonly covered by some kind of vegetation and thus fall into one of the land-use categories.

Grouping of the land surface of the entire earth into only 15 categories is highly generalized and the accuracy of estimates of areal extent is limited by differences in treatment and disagreements among the sources of information. As the classified maps mentioned in the introduction do not give all the required information, it was necessary to consult land-use maps, atlases, regional treatments of agriculture, and monographic works on small areas. Great disagreement was found among these and the choice of sources to be used for any one locality was based on personal experience, knowledge of climate and topography, and confidence in the work of the authors.

TABLE 8. AGRICULTURAL LAND USE

INTENSITY	CATEGORY	AFRICA		ANTARCTICA		AUSTRALASIA		EURASIA				NORTH AMERICA		SOUTH AMERICA		TOTAL	
		AREAL EXTENT		AREAL EXTENT		AREAL EXTENT		WEST OF 60°	EAST OF 60°	ALL OF EURASIA		AREAL	EXTENT	AREAL EXTENT			
		Per-cent	Square miles	Per-cent	Square miles	Per-cent	Square miles	Per-cent	Per-cent	Per-cent	Square miles	Per-cent	Square miles	Per-cent	Square miles	Per-cent	Square miles
60% or more of land cultivated or intensively grazed at any one time	1. Food crops	1.8	207,000	---	---	7.0	238,000	19.0	9.1	12.0	2,472,000	14.8	1,389,000	3.3	227,000	7.9	4,533,000
	2. Intensive grazing (dairying and beef fattening)	---	---	---	---	---	---	0.3	---	0.1	21,000	---	---	---	---	---	21,000
	3. Mixed food crops and intensive grazing	0.8	92,000	---	---	---	---	0.5	0.1	0.2	42,000	---	---	---	---	0.3	134,000
	4. Fiber and other non-food crops	0.1	11,000	---	---	---	---	---	---	---	---	---	---	---	---	---	11,000
	5. Mixed food and non-food agriculture	0.3	34,000	---	---	---	---	---	---	---	---	0.3	28,000	---	---	0.1	62,000
20-60% cultivated or 20-100% range grazing	6. Food crops and range grazing or wasteland	6.5	748,000	---	---	6.5	220,000	9.8	9.2	9.3	1,918,000	5.6	525,000	3.9	268,000	6.4	3,679,000
	7. Food crops, intensive grazing and forest	4.8	552,000	---	---	0.1	3,000	8.6	4.7	5.8	1,195,000	2.3	215,000	1.2	83,000	3.6	2,048,000
	8. Shifting agriculture	7.5	862,000	---	---	0.6	20,000	---	2.0	1.4	289,000	3.6	337,000	9.4	647,000	3.8	2,155,000
	9. Range grazing	27.3	3,140,000	---	---	40.6	1,373,000	9.3	11.5	10.6	2,184,000	14.1	1,323,000	31.9	2,198,000	17.9	10,218,000
Less than 20% agriculture	10. Dense forest; little or no agriculture	5.1	587,000	---	---	10.6	358,000	12.7	24.1	20.1	4,141,000	18.0	1,690,000	35.6	2,452,000	16.1	9,228,000
	11. Open forest or scrub; some light grazing	15.2	1,748,000	---	---	5.0	169,000	0.9	5.9	4.2	868,000	1.0	93,000	7.6	523,000	6.0	3,401,000
	12. Desert or semidesert; very light grazing	28.4	3,266,000	---	---	27.4	927,000	28.5	14.8	18.7	3,855,000	2.5	234,000	1.0	69,000	14.6	8,351,000
	13. Marsh or swamp	1.0	115,000	---	---	0.6	20,000	---	0.6	0.4	83,000	0.3	28,000	0.5	35,000	0.5	281,000
	14. Bog or tundra; little agriculture or reindeer grazing	---	---	3.2	175,000	---	---	6.0	12.2	10.2	2,102,000	24.8	2,328,000	0.7	48,000	8.1	4,653,000
	15. Vegetation low or lacking in mountainous terrain; some grazing and subsistence agriculture	0.5	58,000	---	---	1.6	54,000	3.7	5.4	5.0	1,030,000	0.7	65,000	4.3	296,000	2.6	1,503,000
Perennial snow and ice		---	---	96.8	5,325,000	---	---	0.7	0.4	0.5	100,000	8.4	785,000	0.1	9,000	10.8	6,219,000
Inland water		0.7	80,000	---	---	---	---	---	---	1.5	300,000	3.6	350,000	0.5	35,000	1.3	765,000
Total		100.0	11,500,000	100.0	5,500,000	100.0	3,382,000	100.0	100.0	100.0	20,600,000	100.0	9,390,000	100.0	6,890,000	100.0	57,262,000

SELECTED REFERENCES

- Australia, Department of National Development, 1953-60, Atlas of Australian resources: chap. 1-12, Canberra.
- Bentley, C. R., Cameron, R. L., Bull, C., Kohima, K., and Gow, A. J., 1964, Physical characteristics of the Antarctic ice sheet: Antarctic Map Folio Series, Folio 2, New York, Am. Geog. Soc.
- Black, R. F., 1954, Permafrost - a review: Geol. Soc. America Bull., v. 65, p. 839-856.
- David, T. W. E., 1950, The geology of the Commonwealth of Australia: London, Edward Arnold and Co., v. 1.
- Flint, R. F., 1957, Glacial and Pleistocene geology: New York, John Wiley and Sons.
- Krynine, D. P., and Judd, W. R., 1957, Principles of engineering geology and geotechnics: New York, McGraw-Hill Book Co., Inc., p. 47-80.
- Livingston, C. W., 1956, Fundamental concepts of rock failure, symposium on rock mechanics: Colorado School of Mines Quart., v. 51, no. 3.
- Mellor, Malcolm, 1964, Snow and ice on the earth's surface: Hanover, New Hampshire, U. S. Army Materiel Command, Cold Regions Research and Eng. Lab.
- Moore, H. J., MacCormack, R. W., and Gault, D. E., 1963, Fluid impact craters and hypervelocity-high-velocity impact experiments in metals and rocks: U. S. Geol. Survey, open-file report.
- Morrison, R. G. K., 1947, The rock burst - a study of factors and conditions: Eng. Mining Jour., v. 148, no. 9.
- Peck, R., Hanson, W., and Thornburn, T., 1953, Foundation engineering: New York, John Wiley and Sons.
- Seltzer, L. E. (ed), 1962, The Columbia Lippincott gazetteer of the world: Morningside Heights, New York, Columbia University Press.
- Terzaghi, K., and Peck, R., 1948, Soil mechanics in engineering practice: New York, John Wiley and Sons.
- U. S. Army Engineer Waterways Experiment Station, 1953, Unified soil classification system: Tech. Memo. no. 3-357, v. 1.
- U. S. Army Engineer Waterways Experiment Station, 1958, Effects of a soil-rock interface on cratering: Tech. Rept. 2-478.