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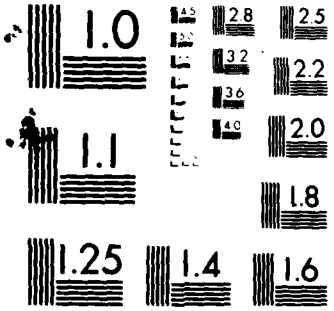

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SOIL PROPERTIES OF USSR STRATEGIC AREAS

Volume I - Soil Property Comparisons for Selected USSR and U.S. Soils

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1 December 1980

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Soils of USSR strategic areas and the MIDDLE GUST test site were compared to evaluate the validity of using MIDDLE GUST geology as representative of radiation energy absorption for USSR strategic areas.

Average Z values were calculated for the USSR and MIDDLE GUST soils using weight and adjusted volumetric methods. Results indicate that porosity and pore water content cause greater variation in the average Z values of

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20. ABSTRACT (Continued)

these soils than does the mineralogic component, and that the method of calculation causes significant differences.

To verify the validity of using the MIDDLE GUST test site for radiation energy absorption calculations of USSR strategic areas, it is recommended that the computer codes use the volumetric (not weight) calculation method and that the vegetation in the USSR areas be assessed for its effect on energy coupling into the ground.

SUMMARY

High-energy radiation deposition from near-surface nuclear bursts is controlled by the opacities of the chemical constituents of the surficial material receiving the incident radiation. DNA's program of benchmark calculations for ground shock and cratering use the geologic characteristics of the *MIDDLE GUST* test site. A comparison study was made of USSR and MIDDLE GUST soils to evaluate the validity of using MIDDLE GUST geology as representative of radiation energy absorption for USSR strategic areas.

Material properties of soils around selected USSR strategic areas were analyzed to provide data for calculating opacities. The USSR generic soil types and chemical compositions differ from those at the MIDDLE GUST test site in Colorado. The average Z values initially calculated based on weight percentages of the elemental chemistry of soils in 18 USSR areas and at the Colorado site were difficult to compare because the soils contained varying amounts of water and humus, and the chemical analyses did not total 100 percent (by weight). The ratio of the two most abundant elements, oxygen and silica, seemed to have a greater mineralogical influence on the average Z values than high Z-number elements such as iron.

Subsequent sets of calculations based on volumetric percentages that included porosity and adjusted the soil components (inorganic solids, humus, water) to total 100 percent produced different average Z values. These calculations indicated that porosity and pore water content cause greater variation in the average Z values of these soils than does the mineralogic component.

The average Z values of soils are not constants but vary as a function of pore water content. For saturated soils, the average Z value of MIDDLE GUST (6.92) is intermediate between the two most representative USSR soils, LARCH (5.83) and TAMARACK (7.06). For dry soils, however, the average Z value for MIDDLE GUST (5.69) is higher than that for LARCH (3.69) and TAMARACK (5.51). This is due primarily to the greater porosity of the two USSR soils.

The differences between the volumetric and weight calculation methods for dry soil conditions are significant; e.g. 3.69 versus 10.34 respectively for LARCH. The differences decrease as the pore water content increases.

Humus has an average Z value of ∿3.4 which is nearly equivalent to that of water (3.3). Thus, abundant organic matter, either as humus in the soil and/or as vegetative cover (peat, grass, brush, trees), could appreciably affect the average Z values of the surficial material in the USSR. The MIDDLE GUST site has a paucity of surface vegetation and humus.

The results of this investigation indicate that soil porosity and pore water content cause greater variations than mineralogic composition in the average Z values of these soils. Consequently, to verify whether the MIDDLE GUST test site can be used to represent USSR strategic areas for radiation energy absorption calculations, the following are recommended:

- The computer codes used to assess radiation absorption of nuclear bursts should evaluate all the soil components (inorganic solid matter, organic matter, pore water) within a volumetric context (incorporate porosity) to properly simulate in situ conditions.

- Vegetation, which could affect energy coupling into the ground, may be an important factor in USSR strategic areas. Its presence in the form of forests or dense ground cover should be investigated to determine whether any significant variations could be expected.
- The average Z values of the other 16 USSR area soils should be recalculated adjusting weight percentages to total 100 and using the volumetric method.

PREFACE

The assistance of the following people is gratefully acknowledged: W. Asano (RDA) for the computer programs to calculate the elemental composition and Z values; K. D. Pyatt (S^3) for discussions on data requirements for computer model calculations and method for calculating average Z values; S. Melzer (CSI) for media property discussions on MIDDLE GUST; R. Nelson (USDA-SCS Lab) for discussions on soil nomenclature and humus composition, and Soviet literature references; J. Rachlin (USGS) for Soviet soil sources; J. Lewis, B. Port and B. Lee (RDA) for discussions on radiation deposition phenomena regarding surficial material, i.e., soil and vegetation; and B. Scott, R. Neiswender, and V. Goldgor (ATI) for Russian-to-English translations of material in the Agrochemistry of the Soils of the USSR volumes.

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I. INTRODUCTION

Current understanding of how near-surface nuclear bursts deposit energy into the ground indicates that a large fraction consists of high-energy radiation deposition. This deposition is controlled by the opacities of the chemical constituents of the surficial material (soil, etc.) receiving the incident radiation.

DNA has a program of benchmark calculations for ground shock and cratering phenomena. These calculations use the geologic characteristics of an area in Colorado where the MIDDLE GUST high-explosive tests were conducted to simulate surface and near-surface nuclear explosions. To evaluate the validity of using MIDDLE GUST to represent the radiation energy absorption characteristics of strategic areas in the USSR, a comparison study was made of USSR and MIDDLE GUST soils.

The chemistry of soils around selected USSR strategic areas was analyzed to provide input for computer models that calculate material opacity. An initial assumption was that the atomic numbers (Z numbers) of the elements composing the soils would affect the opacity characterization of the soils.

The main objectives were (1) to calculate the average Z values of the USSR soils, (2) to compare the USSR soil Z values with MIDDLE GUST Z values, and (3) to assess the significance of soil properties on surficial nuclear radiation deposition into the ground.

MIDDLE GUST was selected as the site for comparison because high-explosive events designed to simulate nuclear environments were detonated at that location in southeastern Colorado. Also, soil property data was available for MIDDLE GUST III. The type of soil at MIDDLE GUST is more similar to the USSR soils than to the primarily carbonate sediments and rocks that constitute the islands at the Pacific Proving Grounds, where large-yield nuclear tests have been conducted.

Eighteen areas in the USSR were selected for soil types to compare with MIDDLE GUST. The locations of these areas are identified in Volume II, which is classified Secret. In this volume, which is unclassified, the areas have arbitrary code names to expedite the use of the data.

The USSR soil data was obtained from the available open literature. Reports on the tests at MIDDLE GUST contained some soil mineralogy and physical property data. The most useful information on the USSR areas was found in USSR soils publications, primarily agricultural in nature. In particular, 15 volumes of the Agrochemistry of the Soils of the USSR (about half of which have been translated into English) contained most of the chemical analyses and physical property data used in this study (Ref. 1).

Soil nomenclature is complex and presents certain difficulties in correlation. Multiple soil classification systems are currently in use, and classification systems have evolved and have been changed over the years. The Russian soil classification is different from that of the United States, in part due to differences in soil genesis factors, which results in some nonequivalent soil types. In addition, the United States adopted a new soil classification system in 1965 that uses newly generated nomenclature essentially unrelated to other systems. The only soil classification system having world coverage is that used by the Federation of Agricultural Organizations-United Nations (FAO-UNESCO) for their Soil Map of the World, which is actually a series of map sheets with explanatory volumes of text (Refs. 2 and 3).

The study approach was first to locate the USSR areas of interest on the FAO soil maps to obtain the soil units for the respective areas. Next, the USSR literature was searched to find the equivalent or nearest equivalent soil type within the selected geographic areas. Although bulk chemical analyses were not available for all of the various soil units in each of the 18 areas, soil chemistry data was sufficient to evaluate the significant soil types in the selected areas.

II. MIDDLE GUST SITE

The MIDDLE GUST test series included five multiton TNT events. MIDDLE GUST III, a spherical 100-ton tangent-to-the-surface (one-radius height-of-burst) test, was designed to reasonably produce direct-induced and airblast-induced ground motions in the proportion expected from a nuclear surface burst (Ref. 4).

1. SITE DESCRIPTION AND SOIL PROPERTIES

The selection of the MIDDLE GUST sites was based on geologic characteristics. The sites are located in Crowley County, southeastern Colorado (Figure 1). The "wet" site is approximately 40 miles east of Pueblo and 5 miles north of Crowley. The "dry" site is about 4 miles northeast of the wet site. Events I, II, III and all calibration experiments were conducted at the wet site. Events IV and V were conducted at the dry site (Ref. 5).

The MIDDLE GUST test sites within the Great Plains physiographic province have local reliefs <1 ft. The wet site (average elevation of 4410 ft) is situated on a level, almost treeless plain lying within a curved section of the Colorado Canal. The canal is the source of a perched water table in the alluvial soil at approximately 4-ft depth at this site. The upper nine feet of material at this site is composed of recent alluvial deposits of mixed sands, silts, and clays. The underlying Cretaceous Pierre shale is nearly 100 percent saturated. An idealized geologic profile of MIDDLE GUST III is shown in Figure 2 (Ref. 6). A summary of physical properties corresponding to the profile are listed in Table 1 (Ref. 4).

The elemental chemical composition of the alluvial soil was determined from two mineralogical analyses of soil samples

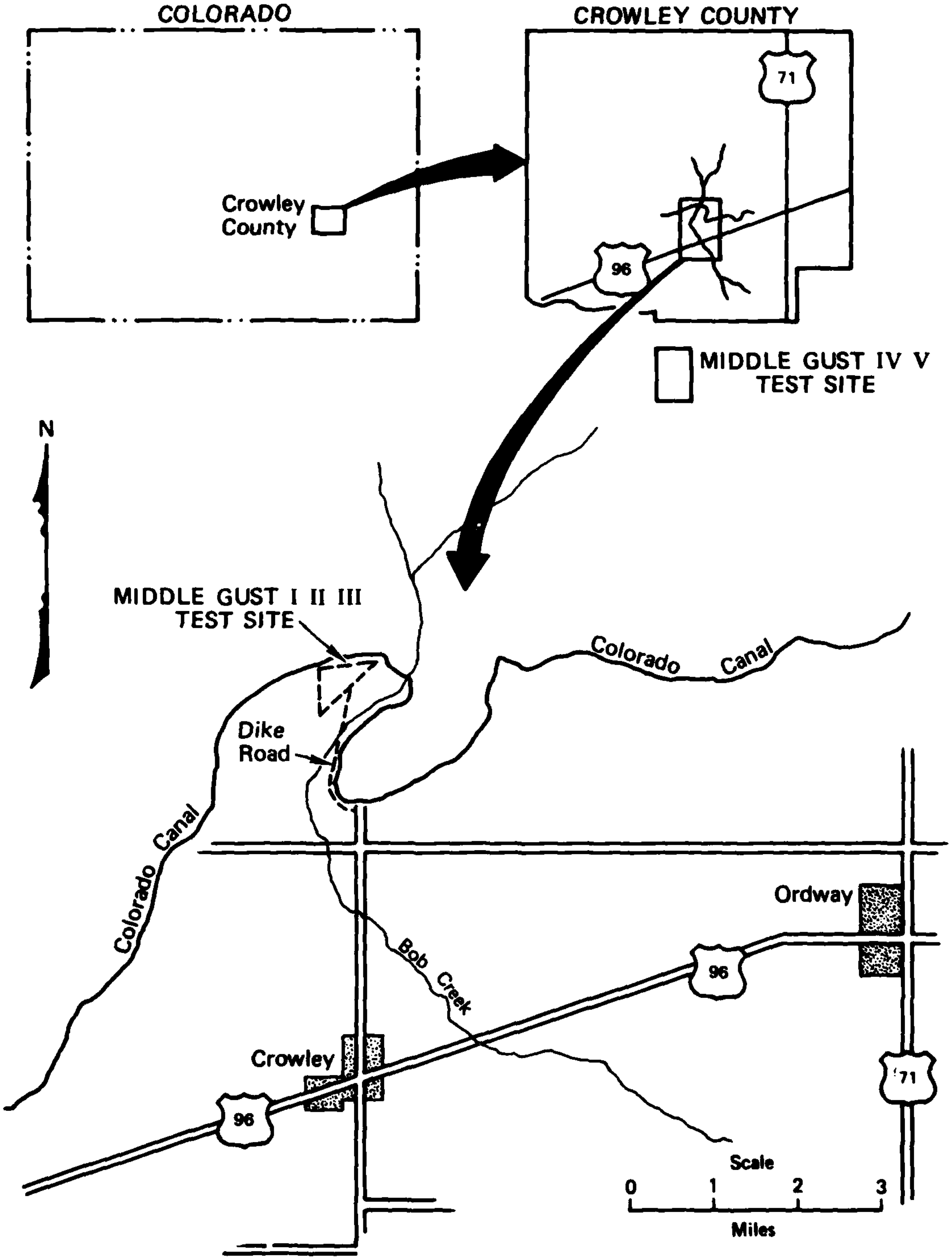


Figure 1. Map of MIDDLE GUST test sites. (Ref. 5)

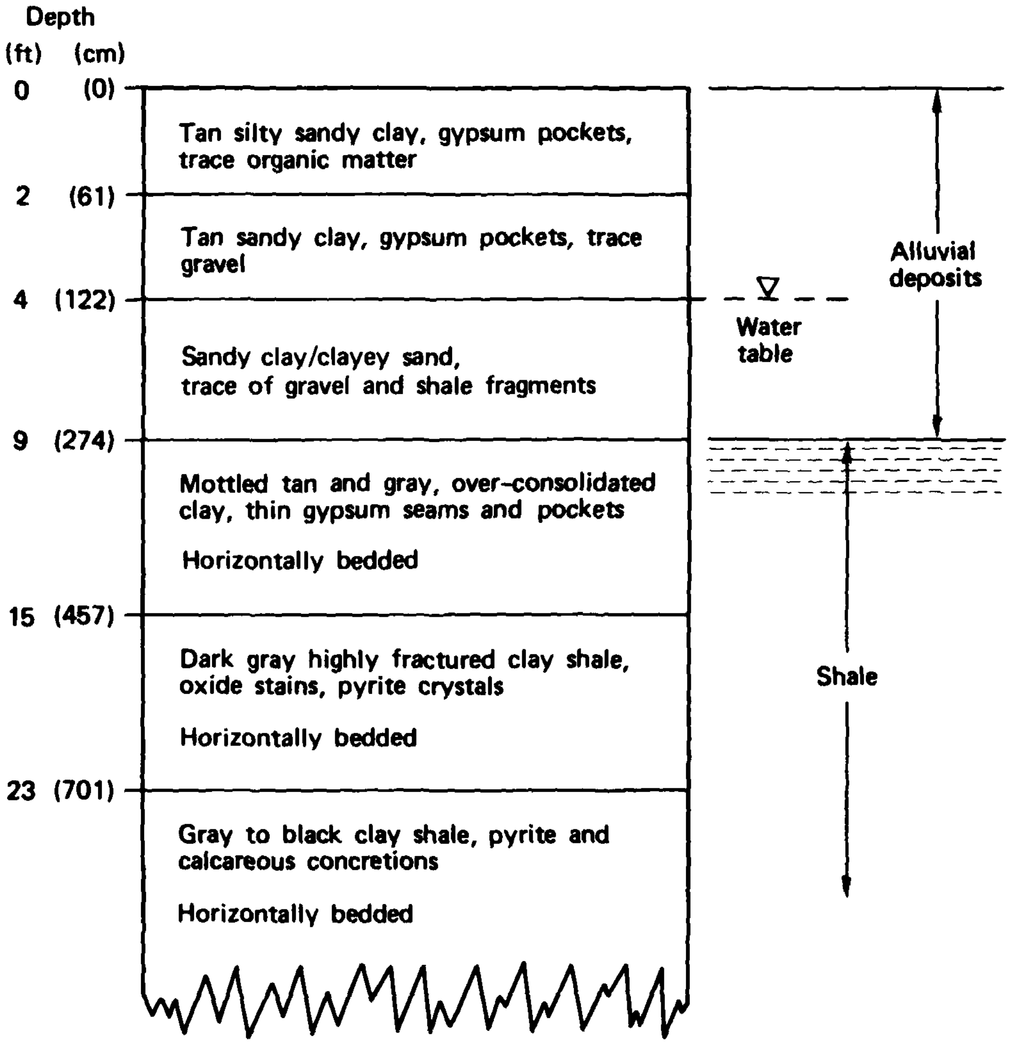


Figure 2. Idealized geologic profile for MIDDLE GUST III test site. (Ref. 6)

TABLE 1. MATERIAL PROPERTIES SUMMARY FOR MIDDLE GUST SITE

Depth (ft)	W (%)	S (%)	γ_d	G_s	V_a (%)	V_w (%)	V_s (%)	γ
0-2	16.2	82.8	111.0 PCF	2.73	6.0	28.8	65.2	129.0 PCF
2-4	14.4	91.6	119.0 PCF	2.72	2.5	27.4	70.1	136.1 PCF
4-9	19.6	97.2	110.0 PCF	2.74	1.0	34.6	64.4	131.6 PCF
9-15	21.5	98.0	107.0 PCF	2.75	0.8	36.8	62.4	130.0 PCF
15-23	12.0	97.2	126.6 PCF	2.71	0.7	24.4	74.9	141.8 PCF
23-45	8.5	97.3	136.5 PCF	2.71	0.6	18.6	80.8	148.0 PCF

(Ref. 4)

W = moisture content (weight %)

S = degree of saturation

γ_d = initial dry unit weight

G_s = specific gravity of solids

V_a = initial volume of air

V_w = initial volume of water (volume %)

V_s = initial volume of solids

γ = wet unit weight

taken at depths of 1.8 ft (55 cm) and 2.2 ft (67 cm) at the MIDDLE GUST III site. Ten percent water content by weight was assumed. The category designated as "Loss_I" represents ignition losses above 100°C and was assumed to be organic matter. These elemental values are shown in Table 2.

2. AVERAGE ATOMIC NUMBER (Z) CALCULATIONS

A computer program was used to calculate elemental and average Z values for the MIDDLE GUST and USSR soils based on given weight percentages of soil analyses. The procedure for these calculations is presented in Appendix A. The Z numbers for the soil elements are listed in Table 2 (these are unit numbers approximately half of their respective atomic weights). The average Z value of MIDDLE GUST III based on Table 3 is 7.60 (Ref. 7). This value is lower than those for USSR soils.

TABLE 2. SOIL ELEMENTS, ATOMIC NUMBERS, AND ATOMIC WEIGHTS

Element	Symbol	Atomic number (Z)	Atomic weight
Aluminum	A	13	26.9815
Barium	Ba	56	137.34
Boron	B	5	10.811
Calcium	Ca	20	40.08
Carbon	C	6	12.01115
Chromium	Cr	24	51.996
Cobalt	Co	27	58.9332
Copper	Cu	29	63.54
Hydrogen	H	1	1.00797
Iodine	I	53	126.9044
Iron	Fe	26	55.847
Lead	Pb	82	207.19
Magnesium	Mg	12	24.312
Manganese	Mn	25	54.938
Molybdenum	Mo	42	95.94
Nickel	Ni	28	58.71
Nitrogen	N	7	14.0067
Oxygen	O	8	15.9994
Phosphorus	P	15	30.9738
Potassium	K	19	39.102
Silicon	Si	14	28.086
Sodium	Na	11	22.9898
Sulfur	S	16	32.064
Titanium	Ti	22	47.90
Strontium	Sr	38	87.62
Zinc	Zn	30	65.37

TABLE 3. ASSUMED ELEMENTAL COMPOSITION OF MIDDLE GUST SOIL*

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
55-70	O	54.91	Fe	2.29
	Si	24.25	Ti	0.07
	Ca	6.61	Ca	6.61
	Al	4.09	K	0.79
	S	3.07	S	3.07
	Fe	2.29	Si	24.25
	H	1.77	Al	4.09
	C	0.86	Mg	0.34
	K	0.79	Na	0.14
	Mg	0.34	O	54.91
	Na	0.14	C	0.86
	Ti	0.07	H	1.77
	Loss_I**			

(Ref. 7)

*Includes 10 percent pore water by weight.

**Loss_I represents ignition losses above 100°C in illite that were left unspecified in the Encyclopedia of Chemical Technology. Probably oxygen, hydrogen and carbon (perhaps a little sulfur).

III. USSR AREAS

Eighteen areas in the USSR were selected for analyzing the soil chemistry and other material properties that could affect radiation deposition. The geographic locations of these areas are identified in Volume II of this report. The areas were given the code names of ALDER, BIRCH, CEDAR, DOGWOOD, ELM, FIR, SPRUCE, HEMLOCK, CYPRESS, JUNIPER, TAMARACK, LARCH, MAPLE, ASPEN, OAK, PINE, SEQUOIA, and REDWOOD to expedite the use of the data.

1. SOIL DESCRIPTIONS

The FAO soil classification system consists of 26 categories and 103 sub-categories, for a total of 129 soil units. For the USSR areas investigated, only 14 (11 percent) of these soil units occur in major amounts, whereas 26 soil units occur in lesser or minor amounts. The FAO map units for the USSR areas are presented in Appendix B. The Soviet soil types of these areas are given in Table 4. The podzolic soils are the most prevalent, and the chernozems are second. The bog/meadow/gley groups of soils, forest soils, and chestnut soils are less extensive. Least extensive are alluvium/regolith and solonetz. Estimated percent of occurrence of these soil types is shown in Table 5. Four of the areas are characterized as having shallow mountain soils: BIRCH, CEDAR, ELM, and JUNIPER.

The major soil types tend to occur as roughly east-west zones in much of the USSR, albeit with irregular boundaries and inclusions of other soil types. Other portions of the country, which have a complex mix of soil types, commonly are in hilly to mountainous terrain where soils are poorly developed and shallow.

TABLE 4. SOIL TYPES FOR USSR AREAS

Area	Soviet equivalents to FAO soil units[a]
ALDER	Podzolic gley soils, meadow soils, weathered regolith [alluvial soils, chernozems?][b]
BIRCH	Shallow mountain soils: ortho-podzolic and regolith [chernozems]
CEDAR	Shallow mountain soils: ortho-podzolic and regolith [meadow gray forest soils, gray forest soils]
DOGWOOD	Derno-podzolic soils, meadow gray forest soils [fertile alluvial soils ?, bog soils ?]
ELM	Shallow mountain soils: gray forest and ortho-podzolic; chernozems [tundra gley soils ? - permafrost regolith]
FIR	Calcic chernozems, typic chernozems. Linears of dunes/shifting sands
SPRUCE	Kastanozems[c] [solonetz]
HEMLOCK	Kastonozems
CYPRESS	Calcic chernozems[c] [kastanozems ?, solonetz ?]
JUNIPER	Shallow mountain soils: gray forest and ortho-podzolic; gray forest soils, shallow organic weathered regolith, podzolized chernozems
TAMARACK	Derno-podzolic soils; podzolized brown forest [shallow organic weathered regolith]
LARCH	Typic chernozems [kastanozems ?]
MAPLE	Derno-podzolic soils [bog soils ?]
ASPEN	Derno-podzolic soils [podzolized brown forest ?]
OAK	Derno-podzolic soils
PINE	Derno-podzolic soils
SEQUOIA	Podzolic gley soils; bog soils, fertile alluvial soils [podzolic gley soils ?]
REDWOOD	Typic chernozem

[a] More detailed presentation of FAO-derived soil units is given in Appendix B.

[b] [ ] are soil types of limited areal extent.

[?] are soil types that may be outside the areas of interest.

[c] Soil nomenclature in the USSR literature does not always conform to the FAO equivalents nor is it internally consistent. For example, kastanozems are probably chestnut soils and calcic chernozems are probably southern chernozems.

TABLE 5. OCCURRENCE OF SOVIET SOIL TYPES FOR STRATEGIC AREAS INVESTIGATED

Soil type	Estimated occurrence (%)
Podzols	40
Chernozems	25
Bog/meadow/gley	10
Gray/brown forest	10
Chestnut (kastanozems)	10
Alluvium/regolith	5
Solonetz	Minor

2. SOIL ANALYSES

Bulk chemical analyses were found for soils in all the areas, except for CEDAR, ELM, FIR, SPRUCE, and ASPEN. CEDAR is geographically close to and in the same soil zone as BIRCH. ELM is in an area of mixed and shallow soils. It relates closest to DOGWOOD geographically, but closer to BIRCH regarding soil zone. FIR occurs in the same distinctive soil zone as CYPRESS, but is not geographically close. SPRUCE occurs in the same soil zone as HEMLOCK and at a moderate geographic distance. ASPEN is geographically very close to MAPLE and in the same massive soil zone. Thus, the areas for which soil chemistry data were unavailable seem to be adequately represented by the other areas. Table 6 lists the areas and their respective appropriate soil types having chemical analyses.

TABLE 6. USSR AREAS AND SOIL TYPES HAVING SOIL CHEMISTRY ANALYSES

Area	Soil type
ALDER	Brown forest gley - podzolized
ALDER	Deep meadow chernozemlike
ALDER	Brown forest podzolized
BIRCH	Chernozems
DOGWOOD	Strongly podzolized
DOGWOOD	Weakly podzolized
HEMLOCK	Chestnut loam
CYPRESS	Southern chernozem (YB clay base)
CYPRESS	Southern chernozem (K clay base)
JUNIPER	Strongly podzolic
JUNIPER	Podzolized chernozem
TAMARACK	Sod podzolic loamy
TAMARACK	Gray forest loamy
LARCH	Typical chernozem
MAPLE	Podzolic clay
MAPLE	Podzolic clay - fine fraction
OAK	Sod podzolic heavy clay
OAK	Sod podzolic heavy clay - fine fraction
OAK	Sod podzolic clay (glacial base)
OAK	Sod podzolic clay (glacial base) - fine fraction
PINE	Bog soils (30)
PINE	Bog soils (59)
SEQUOIA	Soddy podzolic sandy loam
SEQUOIA	Soddy podzolic sandy loam - silt fraction
REDWOOD	Regraded chernozems

The source data for the bulk chemical analyses generally consisted of oxides of the solid constituents and a loss constituent expressed in percent by weight. The loss constituent was usually designated as that portion of the sample lost due to drying by heating (ignition). The composition of the loss constituent is probably primarily organic matter and/or water. The amount of humus and/or hydroscopic water was given for only a few of the analyzed soils.

Source data on soil microelements consisted of values for USSR soil types and for a few specific areas (Ref. 8). Microelement data on molybdenum, zinc, copper, cobalt, manganese, and titanium for USSR soil-forming rocks and soils are given in the tables in Appendix C. Generally, if the amount of a microelement is $\geq$0.01 percent, it is included as part of the bulk chemical analysis. The microelement content of soil, water, and plants is available for the Orenburg region of the USSR, and the microelement content of chernozems in the LARCH area is given in Section IV. Evaluation of this data indicated that the minute amounts of microelements, even though of relatively high Z number, did not cumulatively have an appreciable effect on the average Z values.

The sampled soils, which ranged in depth from 80 to 205 cm, were discontinuous and consisted of up to eight intervals. The chemical analyses for the individual intervals did not always total to 100 percent: some were less and some were greater. Physical property data such as specific gravity, bulk density, porosity, and field capacity were available for only a few areas. The possible implications of some of these analysis characteristics and physical properties will be discussed in Section IV.

A computer program was used to convert the source data to elemental percentages. The elemental composition for each analyzed soil is given in Appendix D. The depth intervals were grouped into three categories: 0-40 cm, 40-150 cm, and >150 cm. These categories were based on the natural division of A, B, and C soil horizons, which reflect chemical and physical changes in soil profiles. Chemical analyses of the fine fraction (<0.0001 mm) were available for MAPLE and OAK, and chemical analyses of the silt fraction were available for SEQUOIA. A summary of the elemental compositions of the USSR soils compared with MIDDLE GUST is shown in Table 7.

3. AVERAGE ATOMIC NUMBER (Z) CALCULATIONS

Average Z values initially were computer calculated using the given weight percentages for depth intervals of 0-40 cm, 40-150 cm, and 150-205 cm for 21 soils in the USSR selected areas. For the 0- to 40-cm-depth interval they ranged from 7.50 to 10.07; for the 40- to 150-cm interval from 8.18 to 10.47; and for the 150- to 205-cm interval from 9.34 to 10.35 (Tables 8, 9, and 10).

These Z values suggest a somewhat apparent relationship to soil type, generally increasing in value in the following order: chestnut, chernozem, forest, podzolic, bog/gley/soddy. However, soil mineralogy does not appear to be the controlling factor (e.g., amount of high Z-number elements such as Fe and Mn). Water content (porosity) and humus also affect the average Z values. Properties that influence Z values for soils are addressed in Section IV.

TABLE 7. SUMMARY OF ELEMENTAL COMPOSITION OF SELECTED USSR AND MIDDLE GUST SOILS (% BY WEIGHT)

Element	Z number	MIDDLE GUST[a] (%) 55-70 cm	USSR areas						
			Range (%)	Sample average[b] (%)			Sample number[c]		
				0-40 cm	40-150 cm	>150 cm	0-40 cm	40-150 cm	>150 cm
Fe	26	2.29	0.29-6.70	3.06	3.41	4.08	21	20	4
Mn	25	---	0-1.83	0.28	0.19	0.98	11	10	2
Ti	22	0.07	0-1.06	0.67	0.51	0.60	3	2	1
Ca	20	6.61	0.16-9.92	1.75	1.95	1.24	21	20	4
K	19	0.79	0-1.73	1.23	1.08	1.48	11	11	2
S	16	3.07	0-0.50	0.16	0.16	0.13	9	9	2
P	15	---	0-0.43	0.05	0.05	0.17	17	17	3
Si	14	24.25	25.03-44.23	33.95	33.15	34.34	21	20	4
Al	13	4.09	0.95-13.41	6.76	7.91	7.36	21	20	4
Mg	12	0.34	0.05-2.15	0.75	0.86	1.08	21	20	4
Na	11	0.14	0-1.26	0.86	0.62	0.52	10	10	2
O	8	54.91	43.73-59.68	53.47	52.38	51.53	21	20	4
N	7	---	0-0.22	0.18	0.07	---	4	4	---
C	6	0.86	0-2.66	1.22	0.79	0.54	19	17	4
H	1	1.77	0-1.48	0.66	0.40	0.30	19	17	4
Other	*	0.81	n.d.-14.77						

*Usually loss due to drying/heating sample. Assumed to be primarily water and/or organic matter, which have an average Z value of ∿3.3.

[a] Assumed 10 percent pore water by weight contained in the sample.

[b] Arithmetic average of those samples containing the element.

[c] Number of samples containing the element.

TABLE 8. SOIL ANALYSES WEIGHT PERCENTAGES AND AVERAGE Z VALUES FOR SELECTED AREAS IN THE USSR (0- TO 40-CM DEPTH INTERVALS)

Area	Soil type	Depth (cm)	Percent of samples (wt)				Average Z value (wt %)
			Elements	Loss	Humus*	Water*	
PINE	Bog (30)	5-35	95.67	3.03	(3.03)		9.57
	Bog (59)	0-35	90.79	---			10.07
OAK	Sod med. podzolic clay	1-40	100.57	4.90	(4.90)	1.64	8.98
	Sod podzolic clay (G)	8-30	99.38	3.96	(3.96)	1.11	9.16
MAPLE	Podzolic clay	8-40	96.90	2.65	(2.65)	1.41	9.32
TAMARACK	Sod med. podzolic loamy	0-31	88.06	2.6	(2.6)		9.69
	Gray forest loamy	2-37	97.92	3.2	(3.2)		9.67
DOGWOOD	Lt gry strongly podzolized	0-32	99.13	6.5	(6.5)		8.98
	Drk gry weakly podzolized	0-28	100.46	8.53	(8.53)		8.86
SEQUOIA	Soddy-med. podzolic loam	0-40	98.59	---			10.07
ALDER	Brn forest gley podzolized	0-30	98.82	10.6	(10.6)		8.51
	Brn forest podzolized	0-34	99.64	8.49	(8.49)		8.79
	Deep meadow (chern)	0-36	99.93	9.17	(9.17)		8.72
JUNIPER	Strongly podzolic	AA-AB	99.26	5.6	(5.6)		9.29
	Podzolic chernozem	0-43	90.25	10.67	(10.67)		8.35
REDWOOD	Regraded chernozem	Ar	102.12	8.47	(8.47)		8.73
LARCH	Typical chernozem	0-38	85.98	14.77	(14.77)		7.85
CYPRESS	Southern chernozem (Y-B)	0-27	104.74	5.4	(5.4)		7.59
	Southern chernozem (K)	0-20	90.3	4.8	(4.8)		8.35
BIRCH	Chernozem	0-30	107.56	4.65	(4.65)		8.17
HEMLOCK	Chestnut loamy	0-28	100.63	6.44	(6.44)		8.68

*( ) = Assumed

TABLE 9. SOIL ANALYSES WEIGHT PERCENTAGES AND AVERAGE Z VALUES FOR SELECTED AREAS IN THE USSR (40- TO 150-CM DEPTH INTERVALS)

Area	Soil type	Depth (cm)	Percent of samples (wt)				Average Z value (wt %)
			Elements	Loss	Humus*	Water*	
PINE	Bog (30)	55-135	90.74	---			10.47
	Bog (59)	45-80	98.81	---			10.03
OAK	Sod med. podzolic clay	60-108	101.65	3.86	(3.86)	2.81	8.95
	Sod podzolic clay (G)	50-150	101.25	4.25	(4.25)	3.12	8.82
MAPLE	Podzolic clay	45-150	101.15	4.89	(4.89)	2.83	8.82
TAMARACK	Sod med. podzolic loamy	56-120	88.95	0.6	(0.6)		10.28
	Gry forest loamy	61-91	100.74	0.6	(0.6)		10.27
DOGWOOD	Lt gry strongly podzolized	45-130	98.42	4.15	(4.15)		9.43
	Drk gry weakly podzolized	55-90	99.24	4.45	(4.45		9.50
SEQUOIA	Soddy-med. podzolic loam	50-110	99.89	---			10.07
ALDER	Brn for gley podzolized	55-130	97.3	4.03	(4.03)		9.49
	Brn for podzolized	40-70	99.08	3.3	(3.3)		9.48
	Deep meadow (chern)	44-144	99.8	3.82	(3.82)		9.53
JUNIPER	Strongly podzolic	B1-B	99.78	3.5	(3.5)	9.73	9.73
	Podzolic chernozem	62-105	92.06	7.3	(7.3)		8.90
REDWOOD	Regraded chernozem	N/A					
LARCH	Typical chernozem	50-105	91.01	10.45	(10.45)		8.47
CYPRESS	Southern chernozem (Y-B)	40-150	109.13	1.2	(1.2)		8.18
	Southern chernozem (K)	40-90	100.0	0.9	(0.9)		8.50
BIRCH	Chernozem	40-150	106.36	0.32	(0.32)		8.67
HEMLOCK	Chestnut loamy	100-150	98.06	9.99	9.99		8.27
MIDDLE GUST	Xerosol/regosol (alluvial)	55-70	89.19	0.81	(0.81)	(10.0)	7.60

*( ) = Assumed

TABLE 10. SOIL ANALYSES WEIGHT PERCENTAGES AND AVERAGE Z VALUES FOR SELECTED AREAS IN THE USSR (FINE FRACTIONS AND 150- TO 200-CM DEPTH INTERVALS)

Area	Soil type	Depth (cm)	Percent of samples (wt)				Average Z value (wt %)
			Elements	Loss	Humus*	Water*	
Fine fractions: <0.0001 mm							
OAK	Sod med. podzolic clay	1-40	105.37	7.58	(7.58)	9.44	7.74
	Sod med. podzolic clay	60-108	103.55	8.26	(8.26)	10.51	7.55
OAK	Sod podzolic clay	8-30	102.29	12.83	(12.83)	5.38	7.67
	Sod podzolic clay	50-150	106.86	12.55	(12.55)	8.35	7.49
MAPLE	Podzolic clay	8-40	103.9	7.72	(7.72)	8.25	7.85
		45-150	103.14	7.59	(7.59)	9.86	7.66
Silt fraction:							
SEQUOIA	Soddy-med. podzolic loam	0-40	101.59	---			10.27
		50-100	99.26	---			10.33
Deeper intervals:							
TAMARACK	Gry forest loamy	153-163	100.91	0.7	(0.7)		10.35
DOGWOOD	Lt gry strongly podzolized	195-205	97.82	4.3	(4.3)		9.36
DOGWOOD	Drk gry weakly podzolized	160-170	99.56	5.3	(5.3)		9.34
ALDER	Brn forest podzolized	160-170	98.97	1.58	(1.58)		9.81

*( ) = Assumed

IV. SOIL PROPERTIES AND COMPARISONS

Two of the eighteen USSR areas investigated have been selected for comparison with the MIDDLE GUST III site. TAMARACK represents the soil type most common for the USSR areas investigated and has one of the highest average Z values (using the initial set of calculations by weight percentages). LARCH was selected because it represents the second most common soil type and because data on microelements having high Z numbers was available for that area.

1. SOIL PROPERTIES OF SELECTED AREAS

Tables 11 through 15 show the data for the adjusted field-sample properties for these three areas. For the MIDDLE GUST soil, the 10 percent by weight pore water (Table 3) was listed separately and the 0.81 percent loss fraction was assumed to be humus. For the LARCH soil, microelements were added (Appendix C) and sufficient water was added to obtain 100 percent total by weight. For TAMARACK, sufficient water was added to obtain 100 percent total by weight.

Of these three areas, the MIDDLE GUST soil had the highest dry bulk density (1.78) and lowest porosity (35 percent). LARCH soil had the lowest dry bulk density (1.10 in the A horizon, 1.51 in the B-C horizons) and highest porosity (57 percent in the A horizon, and 45 percent in the B-C horizons). TAMARACK soil had intermediate dry bulk density (1.59) and porosity (40 percent in the A horizon, 41 percent in the B-C horizons).

The moisture contents by weight of these three soils were 10 percent for MIDDLE GUST, 7.6 percent (A horizon) and 3.9 percent (B-C horizons) for LARCH, and 9.3 percent (A horizon) and 10.5 percent (B-C horizons) for TAMARACK. Humus contents by weight were 0.8 percent for MIDDLE GUST,

TABLE 11. PROPERTIES OF ADJUSTED FIELD SAMPLE: MIDDLE GUST (55- TO 70-CM DEPTH)

Soil Type: Xerosol/Regosol (alluvial sandy clay)

Element	Percent (wt)	Z number
Fe	2.29	26
Ti	0.07	22
Ca	6.61	20
K	0.79	19
S	3.07	16
Si	24.25	14
Al	4.09	13
Mg	0.34	12
Na	0.14	11
O	46.03	8
C	0.86	6
H	0.65	1
	89.19	
Humus		
Ca	0.008	20
O	0.575	8
C	0.146	6
H	0.081	1
	0.81	
Water		
O	8.88	8
H	1.12	1
	10.00	
	100.00	

Specific gravity (grain density):	2.73
Bulk density:	1.78
Porosity:	35%
Field capacity:	N.A.

TABLE 12. PROPERTIES OF ADJUSTED FIELD SAMPLE: LARCH (0- TO 38-CM DEPTH)

Soil Type: Chernozem (A_1-A_2 horizons)

Element	Percent (wt)	Z number
I	0.0002	53
Mo	0.00007	42
Zn	0.0024	30
Cu	0.0007	29
Ni	0.0002	28
Co	0.00026	27
Fe	3.162	26
Mn	0.046	25
Ti	0.358	22
Ca	2.305	20
K	0.600	19
S	0.112	16
P	0.065	15
Si	27.958	14
Al	8.173	13
Mg	0.438	12
Na	0.289	11
O	42.476	8
	85.98583	
Humus		
Ca	0.064	20
O	4.544	8
C	1.152	6
H	0.640	1
	6.4	
Water		
O	6.76138	8
H	0.85279	1
	7.61417	
	100.00	

Specific gravity (grain density): 2.55

Bulk density: 1.10

Porosity: 57%

Field capacity: 37%

(Elements I, Mo, Zn, Cu, Ni, and Co are microelements.)

TABLE 13. PROPERTIES OF ADJUSTED FIELD SAMPLE: LARCH (50- TO 105-CM DEPTH)

Soil type: Chernozem (B_1-C_1 horizons)

Element	Percent (wt)	Z number
I	0.00098	53
Mo	0.00086	42
Zn	0.009	30
Cu	0.0018	29
Ni	0.005	28
Co	0.0013	27
Fe	3.112	26
Mn	0.560	25
Ti	0.560	22
Ca	3.3693	20
K	0.722	19
S	0.076	16
P	0.041	15
Si	28.884	14
Al	8.490	13
Mg	0.796	12
Na	0.275	11
O	44.516	8
	91.750	
Humus		
Ca	0.044	20
O	3.124	8
C	0.792	6
H	0.440	1
	4.4	
Water		
O	3.419	8
H	0.431	1
	3.850	
	100.00	

Specific gravity (grain density):	2.75
Bulk density:	1.51
Porosity:	45%
Field capacity:	24%

TABLE 14. PROPERTIES OF ADJUSTED FIELD SAMPLE: TAMARACK (0- TO 31-CM DEPTH)

Soil Type: Sod Podzolic (A_1-A_2 horizons)

Element	Percent (wt)	Z number
Fe	4.84	26
Ca	0.94	20
P	0.02	15
Si	32.32	14
Al	4.55	13
Mg	1.09	12
O	44.12	8
N	0.18	7
	88.06	
Humus		
Ca	0.03	20
O	1.84	8
C	0.47	6
H	0.26	1
	2.60	
Water		
O	8.29	8
H	1.05	1
	9.34	
	100.00	

Specific gravity (grain density):	2.65
Bulk density:	1.6
Porosity:	40%
Field capacity:	29%

TABLE 15. PROPERTIES OF ADJUSTED FIELD SAMPLE: TAMARACK (56- TO 120-CM DEPTH)

Soil Type: Sod Podzolic (B_1-B_2-C_1 horizons)

Element	Percent (wt)	Z number
Fe	5.71	26
Ca	2.61	20
P	0.01	15
Si	29.73	14
Al	5.86	13
Mg	1.41	12
O	43.58	8
N	0.04	7
	88.95	
Humus		
Ca	0.01	20
O	0.42	8
C	0.11	6
H	0.06	1
	0.60	
Water		
O	9.28	8
H	1.17	1
	10.45	
	100.00	

Specific gravity (grain density):	2.7
Bulk density:	1.6
Porosity:	41%
Field capacity:	30%

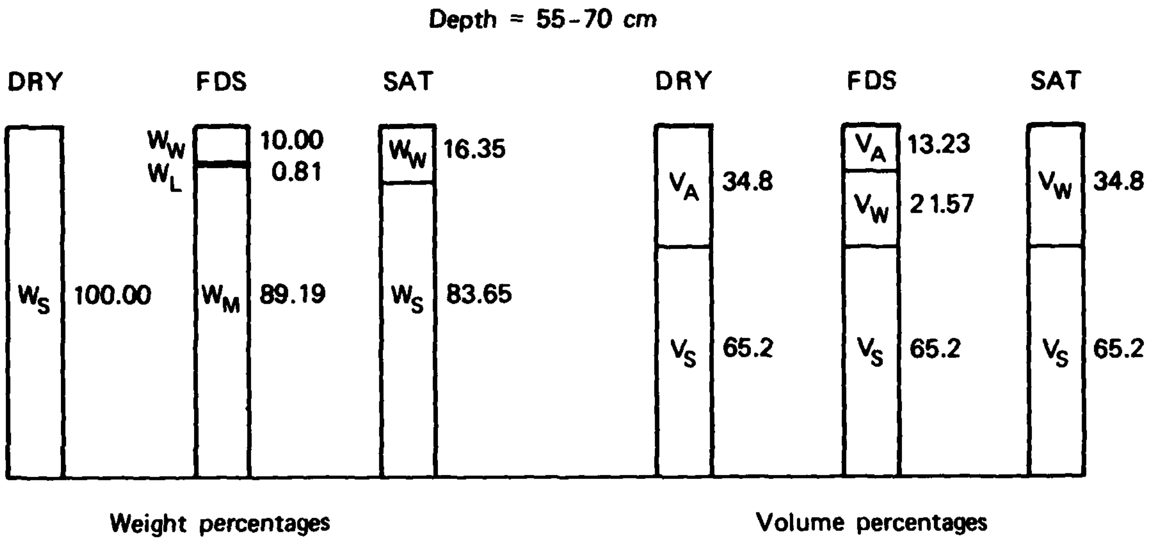
6.4 percent and 4.4 percent for LARCH, and 2.6 percent and 0.6 percent for TAMARACK.

Field capacity is the percentage of water remaining in the soil two or three days after the soil has been saturated and free drainage has practically ceased. It is probably a good estimate for partially saturated soil. Field capacities were 37 percent (A horizon) and 24 percent (B-C horizons) for LARCH, and 29 percent (A horizon) and 30 percent (B-C horizons) for TAMARACK. Field capacity data was not available for the MIDDLE GUST III site.

2. CALCULATION RESULTS

Initially, the percentages of inorganic solids (rock-forming minerals), organic matter (humus), and water content (pore water) were calculated by weight, the method conventionally used. However, when the average Z values were calculated using only weight percentages, it was noted that the values did not properly reflect the in situ soil conditions because the unit volumes of the soils were not incorporated and the elemental analyses did not always total 100 percent. Thus, apparent high average-Z values were biased toward soil samples having low water content and inorganic elemental weight percentages <100 percent. Consequently, accurate comparisons among the soil samples were not possible because they varied in porosity, water content, and total elemental weight percent.

The soil constituent percentages were recalculated adjusting the weight percentages to total 100 and incorporating porosity to obtain volume percentages for MIDDLE GUST, LARCH, and TAMARACK. Figures 3, 4, and 5 illustrate the differences between weight and volume percentages for dry, field sample, and saturated soil conditions for these three locations. The differences are significant, especially as the amount of air-filled voids increases.



W_S = Weight of solids
W_W = Weight of water
W_L = Weight of substances lost in drying sample (water and/or humus)
W_M = Weight of inorganic minerals
(W_A = Weight of air = 0)

V_S = Volume of solids
V_W = Volume of water
V_A = Volume of air

DRY = No water in voids
SAT = Voids completely filled with water
FDS = Field-derived sample - based on both measured and assumed mineralogical constituents
FS = Field sample - chemical analysis of field samples

Figure 3. Weight and volume percentages for MIDDLE GUST soil.

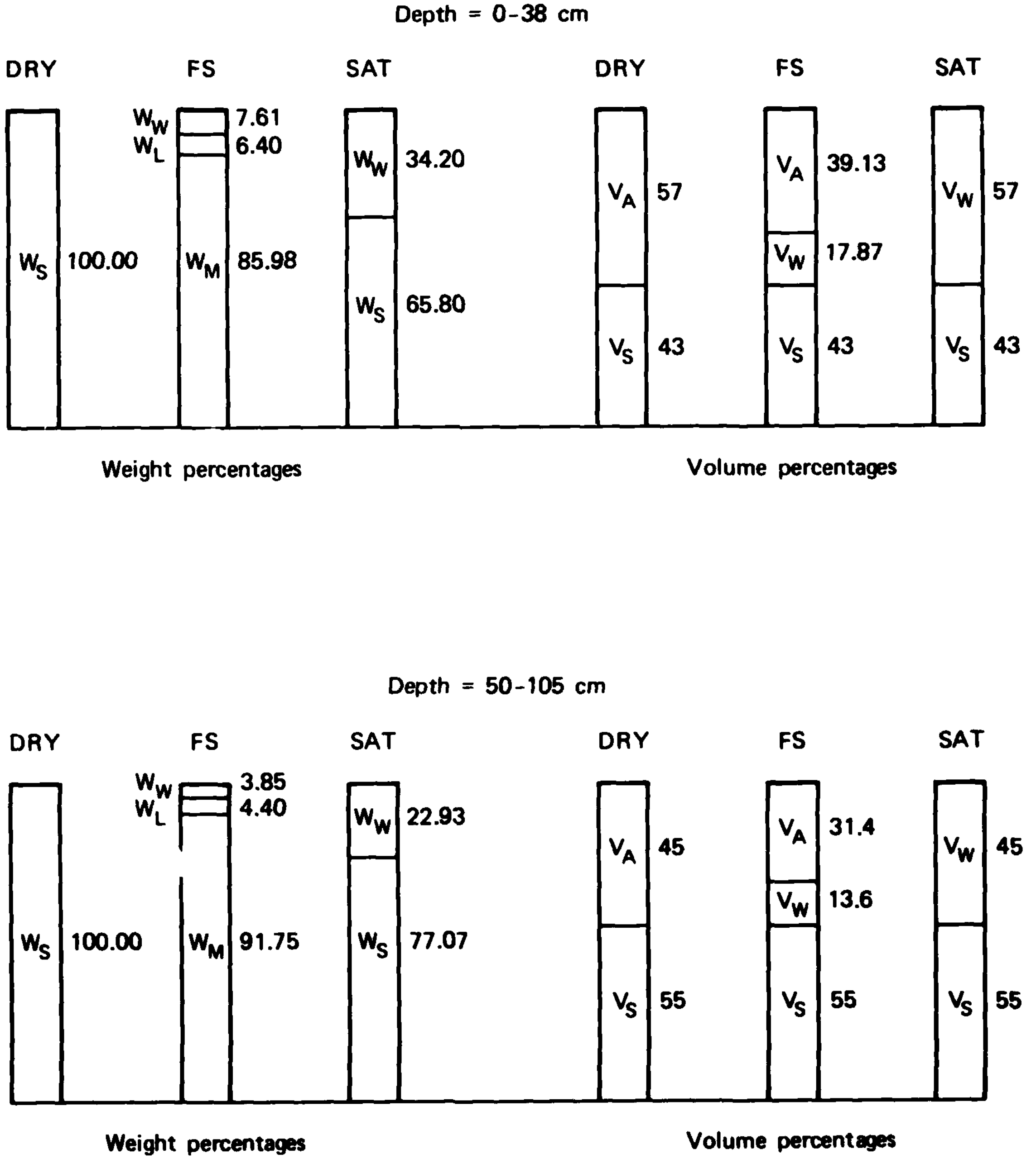


Figure 4. Weight and volume percentages for LARCH soil. (See Figure 3 for explanation of symbols.)

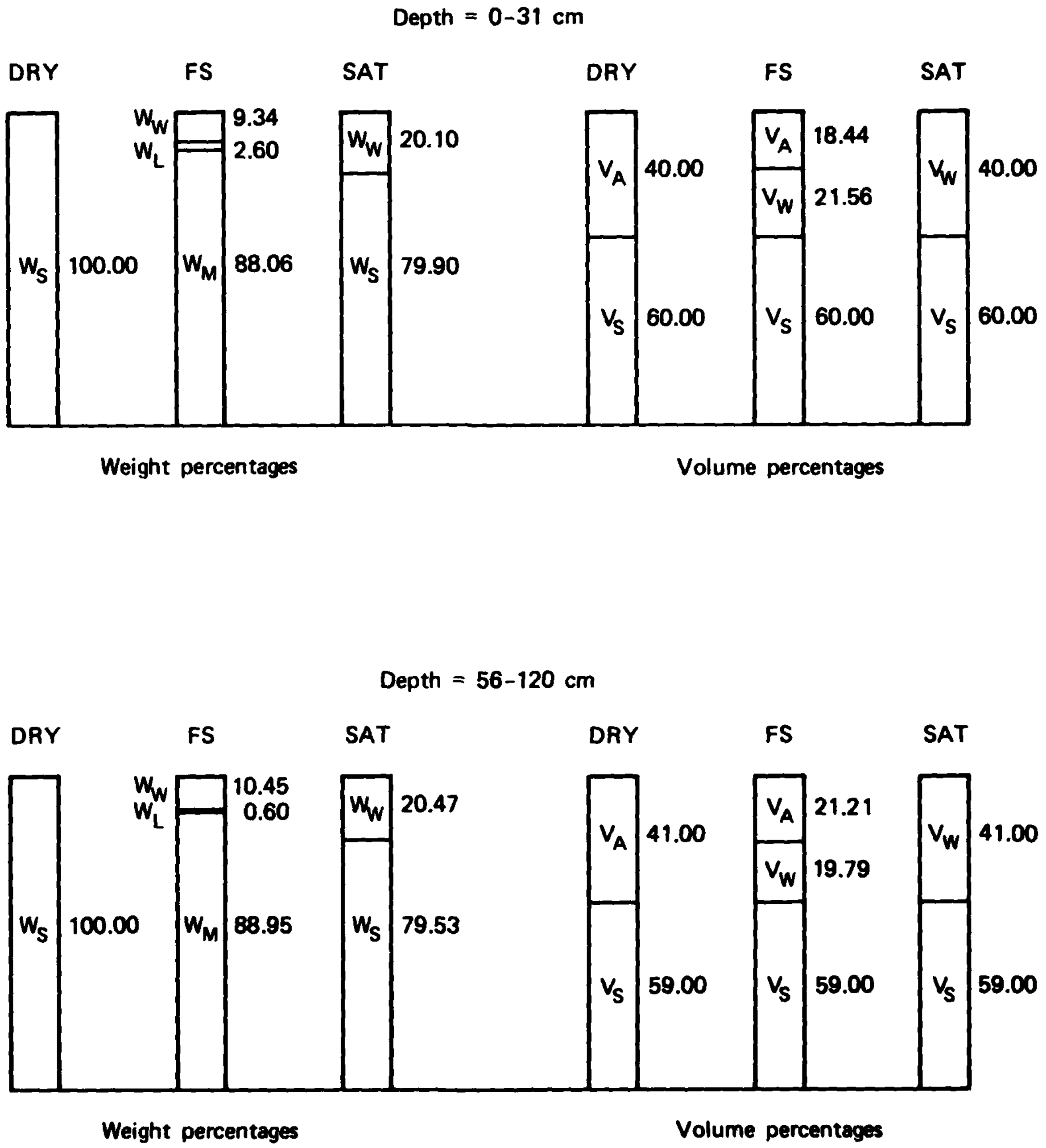


Figure 5. Weight and volume percentages for TAMARACK soil. (See Figure 3 for explanation of symbols.)

Comparison of average Z values calculated using the weight and volume percentages are shown in Figure 6 for MIDDLE GUST, LARCH, and TAMARACK. For the saturated condition the average Z value for each soil location is equivalent for the weight and volume calculation methods. However, as the moisture content of the soil decreases, the average Z value for each soil location diverges. It increases for the weight calculation method and decreases for the volume calculation method. The higher the soil porosity, the greater the divergence of the average Z value between the weight and volume calculation methods for the dry conditions.

The divergence is not great for the MIDDLE GUST field sample because it was nearly saturated and had a porosity of 35 percent. In contrast, the divergence is much greater for the LARCH field sample because it had a porosity of 57 percent, so the water-to-solid ratio was greater. The divergence for TAMARACK is intermediate between MIDDLE GUST and LARCH, as is its porosity of 40 percent.

Figure 6 demonstrates that, by using the weight calculation method, the average Z values for the two USSR soils appear higher than those for MIDDLE GUST for unsaturated conditions. However, with the volume calculation method, the average Z values for the two USSR soils are lower than those for MIDDLE GUST for unsaturated conditions. Except either for a short period after a heavy or long-duration rainfall or for a localized poorly drained area, surface and near-surface soils are normally not saturated. In fact, the water content will vary seasonally and surficial soils tend to have low water content in areas having dry seasons.

Figure 7 shows the differences between the weight and volume percentage calculation methods and the variations with varying water content and porosity. Calculations using

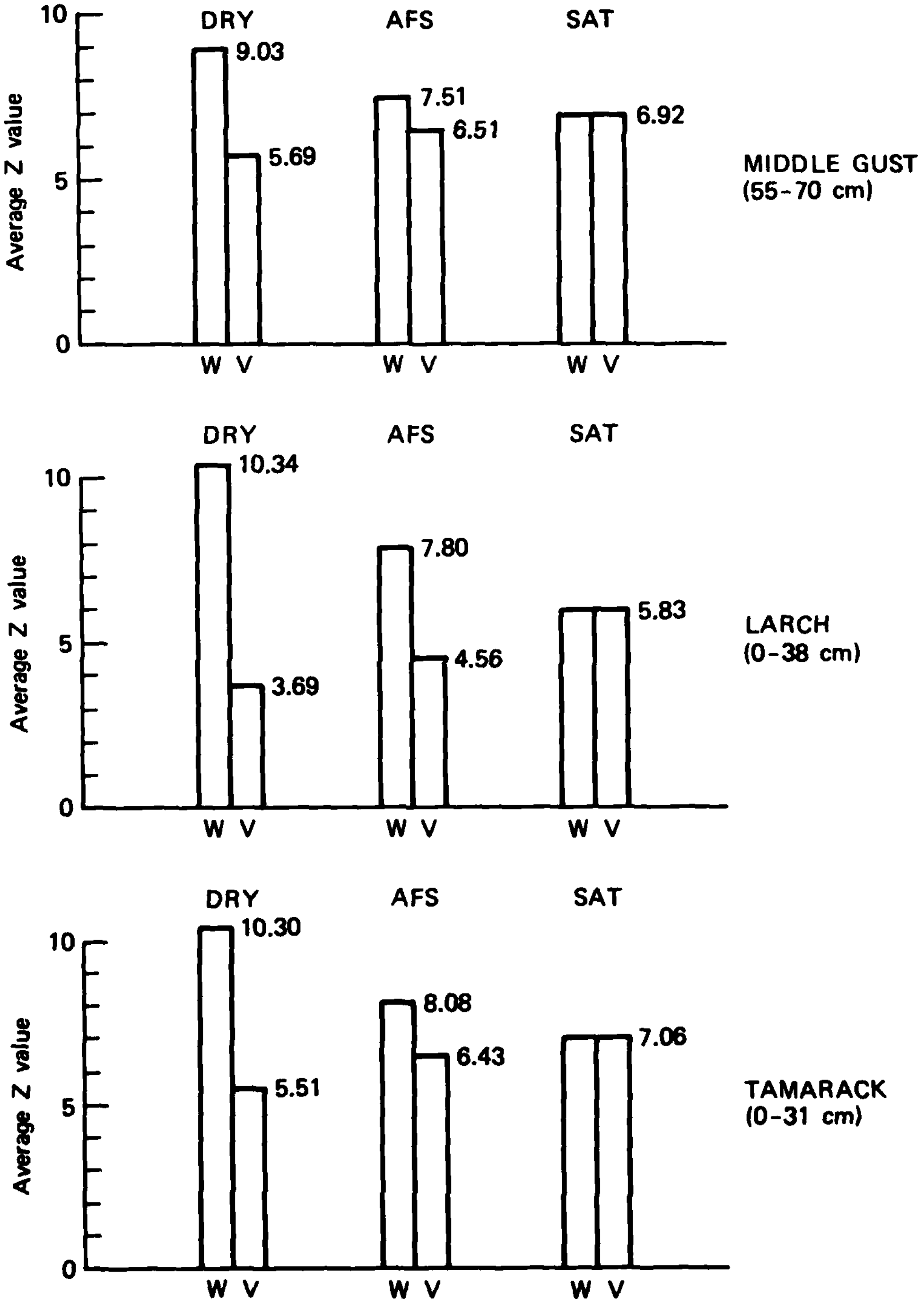


Figure 6. Comparison of weight and volume calculation methods to determine average Z values for MIDDLE GUST, LARCH, and TAMARACK soils.

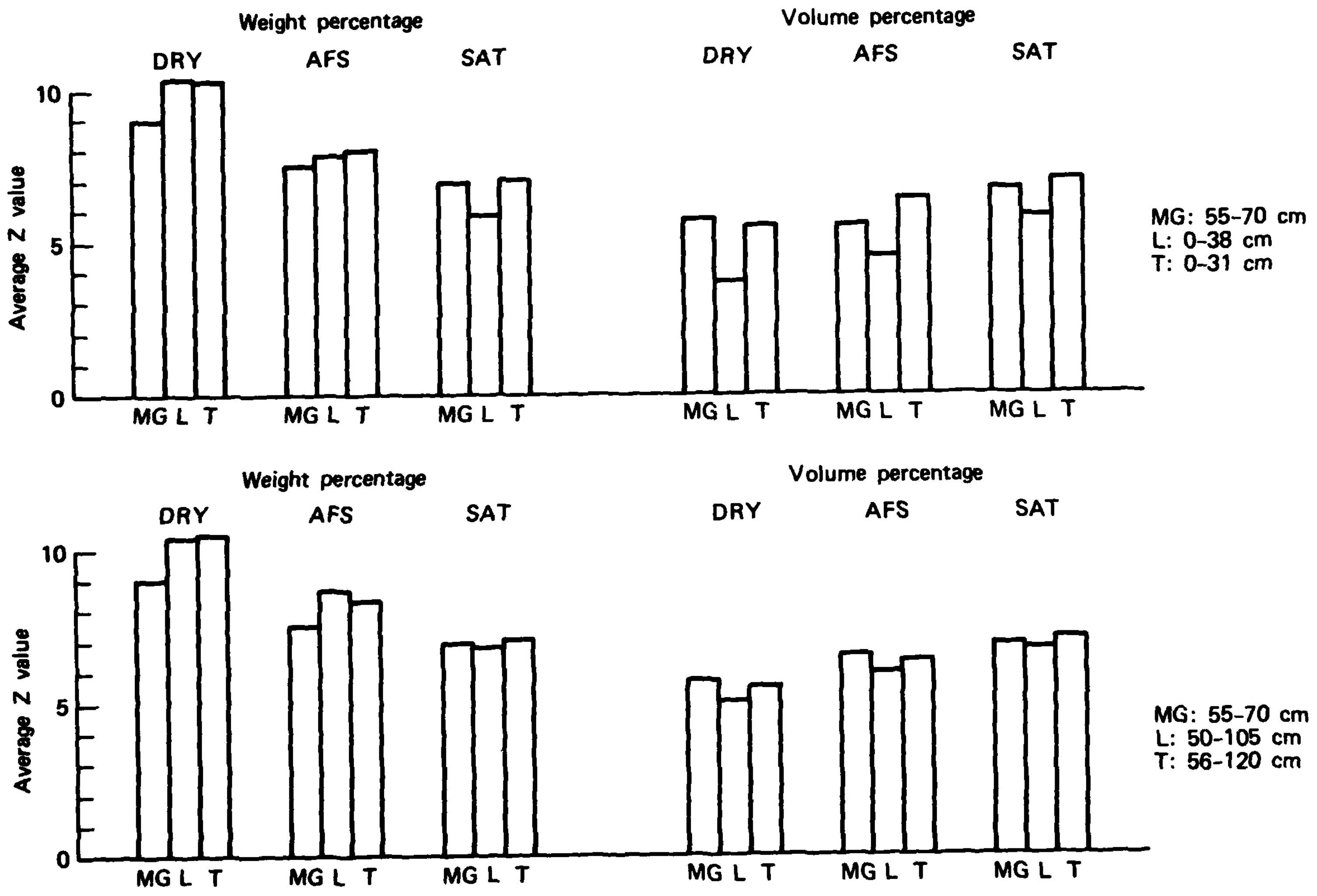


Figure 7. Comparison of MIDDLE GUST, LARCH, AND TAMARACK average Z values for varying water content using weight and volume calculation methods.

the weight percentage method indicate small differences between MIDDLE GUST and the two USSR soils for the dry field-sample moisture content and saturated conditions. Calculations using the volume percentage method indicate that LARCH has lower average Z values than either MIDDLE GUST or TAMARACK: the absolute Z values are least for dry conditions at the top of the soil; the differential Z values are greatest for the same condition; and the differential Z value is least for the saturated condition lower in the soil.

The average Z values for MIDDLE GUST, LARCH, and TAMARACK are summarized in Table 16. Differences in the values as a function of moisture content (dry, adjusted field sample, and saturated) are compared for the three methods of calculation: weight percentage, adjusted weight percentage, and adjusted volume percentage. The results demonstrate that average Z values of soils are not constants, but vary as a function of porosity and water content. Porosity and water content cause greater fluctuations in average Z values of MIDDLE GUST, LARCH, and TAMARACK soils than do the variations in the elemental chemistry of their inorganic mineralogic component.

TABLE 16. SUMMARY OF AVERAGE Z VALUES FOR MIDDLE GUST, LARCH, AND TAMARACK SOILS

Soil location	Depth (cm)	Average Z value weight percent[a]		Average Z value adjusted weight percent[b]			Average Z value adjusted volume percent[c]		
		FS	FDS	DRY	AFS	SAT	DRY	AFS	SAT
MIDDLE GUST	55-70		7.60	9.03	7.51	6.92	5.69	6.51	6.92
LARCH	0-38	7.85		10.34	7.80	5.83	3.69	4.56	5.83
	50-105	8.47		10.40	8.64	6.80	5.10	5.95	6.80
TAMARACK	0-31	9.69		10.30	8.08	7.06	5.51	6.43	7.06
	56-120	10.28		10.43	8.28	7.07	5.49	6.34	7.07

[a] Soil data used as given in the references. Inconsistencies in total percent (100%) and loss constituents. Volume (porosity) not included. Weight percentages normalized during average Z value calculations. (Method used in opacity codes.)

[b] Soil data weight percentages adjusted proportionally to equal 100% prior to average Z value calculations. Volume not included.

[c] Soil data adjusted proportionally to equal 100% incorporating unit volume (porosity) prior to average Z value calculations.

V. DISCUSSION OF FINDINGS

This investigation was initiated on the premise that radiation absorption is sensitive to Z numbers and thus would be affected by variations in the Z values of surficial soil in the vicinity of nuclear bursts. Computer codes designed for calculating radiation absorption have used weight percentages of the inorganic solid component of soils to derive average Z values. The existing codes produce different results depending on whether (and how) other soil characteristics are included.

The first set of calculations based on weight percentages of the elemental chemistry of soils in 18 USSR areas and at the Colorado site produced average Z values that were difficult to compare because the soils contained varying amounts of water and humus, and the chemical analyses did not total 100 percent (by weight). However, the two (perhaps three) most abundant elements in the soils, namely oxygen and silica (plus aluminum), appear to be more important than the highest Z number element of any significant amount (iron) in influencing the average Z values.

The subsequent sets of calculations generated to compare the two most representative USSR soil areas and the U.S. test site produced different average Z values. These calculations were based on volume percentages that included porosity and adjusted the soil components (inorganic solids, humus, water) to total 100 percent. The volumetric calculations indicated that porosity and water content cause greater variations in average Z values of these soils than does the mineralogic component.

The effect of water content on average Z values increases as the porosity of the soil increases. The bog/gley/meadow soils of the USSR would be saturated or nearly saturated much of the year. Other soils would be saturated, at least temporarily, during rainy periods and after some rainstorms. Within a few days after being saturated, depending on drainage characteristics, most soils would reach field capacity. Field capacity would tend to be the more expected condition in areas of adequate drainage.

The porosities of chernozem soils in the USSR are high. They range from about 50 to 60 percent in the A horizon and from about 40 to 60 percent in the B horizon (Tables 17 and 18). Field capacities for chernozems range from about 20 to 40 percent in the A horizon and from about 10 to 30 percent in the B horizon.

The average Z values of water and humus (organic matter) are similar: 3.3 for water and ∿3.4 for humus. The average Z values of the mineralogic (inorganic solid matter) component of the soils are about triple (∿9 to >10) that of water and humus. If the depth of radiation penetration is a function of Z values, then soil density, pore water content, and organic matter are parameters of consequence. If the land surface is covered by a dense, thick cover of vegetation, the radiation may not reach the underlying soil. This may be likely in some of the USSR areas having locally thick surface layers of peat or having forest cover or dense brush. Thus, vegetation should be investigated for its influence on radiation absorption. The MIDDLE GUST site is in a semiarid region of sparse surface vegetation and very little humus.

The average Z values of soils are not constants but vary seasonally due to fluctuations of water content in the soil. In areas of agricultural cultivation, average Z values would also vary as a function of water content changes due to irrigation and of porosity changes due to plowing.

TABLE 17. HYDROPHYSICAL PROPERTIES OF COMMON CHERNOZEMS IN THE USSR

Soil type	Horizon	Depth of sampling (cm)	Porosity (total) (%)	Field capacity (%)	Wilting point (%)	Maximum hydroscopic moisture (%)	True density	Bulk density
Medium-thick	A	0-10	56	20.3	5.9	3.8	2.53	1.21
Light loam	B	40-50	44	12.2	2.9	2.3	2.58	1.45
Chernozem	C_1	50-60	42	10.9	2.8	2.1	2.60	1.51
	C_c	100-110	41	7.4	2.1	1.9	2.63	1.54
Medium-thick	A	0-10	54	30.8	6.8	n.d.	2.57	1.19
Light loam	B	30-40	53	22.8	6.3	n.d.	2.64	1.25
Chernozem	BC	40-50	53	19.6	6.1	n.d.	2.69	1.26
	C_c	90-100	51	16.6	4.5	n.d.	2.68	1.32
Medium-thick	A	0-10	63	30.3	10.5	6.9	2.53	0.93
Heavy loam		10-20	63	30.4	11.3	7.3	2.60	0.96
Chernozem	B	30-35	62	27.9	9.4	7.1	2.56	0.97
	C_c	50-60	57	23.5	8.7	6.0	2.63	1.14
	C_2	70-80	59	21.1	8.3	6.1	2.70	1.10

TABLE 18. PHYSICAL PROPERTIES OF SOILS IN LARCH AREA, USSR

Soil type	Porosity (%)		Field capacity (%)		Wilting point (%)		Specific gravity		Apparent density (gm/cm^3)	
	A*	B*	A	B	A	B	A	B	A	B
General range							2.55	2.75	1.1	1.7
Normal chernozems	54-57	45-50	34-37	24-32	9.5-10.6	8.8-10.0			1.10	1.30-1.41
Southern chernozems	54-57	45-50	34-37	24-32	9.5-10.6	8.8-10.0			1.17	1.40-1.43
Chestnut soils	51-54	37-48	27-33	21-26	9.0-9.7	8.7-9.7			1.24	1.32

*A,B = Soil horizons.

Thus, to properly compare the response of USSR surficial material and U.S. test sites to nuclear explosion effects such as radiation absorption, the following data, assessments, and calculations should be considered to determine degree of sensitivity:

- Determine range in soil porosity as a function of soil type, geographic location, and depth. Check for temporal changes in porosity due to cultivation and other processes.
- Determine variation in the pore water content of the soils as a function of seasonal precipitation, drainage (field capacity), and irrigation.
- Determine variation in the air-filled voids of the soil. Soil porosity (volume percent) = pore water content (volume percent) + air-filled voids (volume percent).
- Determine the elemental chemistry of all soil components: inorganic solids (mineral matter), organic solids (humus, peat, surface vegetation), and pore water.
- Adjust (if needed) weight percentages of solids and water to total 100 percent.
- Calculate average Z values of soils using volumetric method to properly simulate in situ conditions.
- Calculate average Z values of soils varying pore water content from zero to fully saturated to assess maximum range of soil moisture conditions. Use field capacity percentages (by volume) to assess most likely conditions in temperate to humid areas where soil drainage

occurs. Use saturated conditions to assess most likely condition of bog/meadow soils in areas of poor drainage.

- Assess the vegetative cover of the ground surface--peat, grasses, brush, forest. Some of the 18 USSR areas investigated have locally thick accumulations of peat (Volume II).
- Investigate the influence of snow, ice, and permafrost on radiation absorption.

VI. CONCLUSIONS AND RECOMMENDATIONS

- The average Z values of soils are not constants, but vary as a function of pore water content.
- Porosity and water content have a greater effect on average Z values than does the inorganic solid component for the USSR soils investigated and for MIDDLE GUST soil.
- The average Z values of the soils analyzed appear to be influenced more mineralogically by the predominant elements oxygen and silica than by the higher Z-number elements such as iron.
- For saturated soils, the average Z value of MIDDLE GUST (6.92) is intermediate between the two most representative USSR soils, LARCH (5.83) and TAMARACK (7.06).
- For dry soils, however, the average Z value using the volumetric calculation method for MIDDLE GUST (5.69) is higher than that for LARCH (3.69) and TAMARACK (5.51). This is due primarily to the greater porosity of the two USSR soils.
- If only the inorganic solid matter (mineralogy) of the soil is considered and the weight calculation method is used, the average Z value of MIDDLE GUST (9.03) is less than that for LARCH (10.34) and TAMARACK (10.30).
- The differences between the volumetric and weight calculation methods for dry soil conditions are significant; e.g., 3.69 versus

10.34 respectively for LARCH. The differences decrease as the pore water content increases.

- Humus has an average Z value of ∿3.4, which is nearly equivalent to that of water (3.3). Thus, abundant organic matter, either as humus in the soil and/or as vegetative cover (peat, grass, brush, trees), could appreciably affect the average Z values of the surficial material in the USSR.
- The computer codes used to assess radiation absorption of nuclear bursts should evaluate all the soil components (inorganic matter, organic matter, pore water) within a volumetric context (incorporate porosity) to properly simulate in situ conditions.
- The average Z values of the other 16 USSR area soils should be recalculated adjusting weight percentages to total 100 and using the volumetric method.
- Vegetation, which could affect energy coupling into the ground, may be appreciable in nuclear radiation absorption. Its presence in the form of forests (trees) or dense ground cover (brush, grasslands, peat) should be investigated to determine whether any significant variations could be expected. Snow or ice covering the ground also may alter energy coupling into the underlying soil.

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APPENDIX A. METHOD FOR CALCULATING AVERAGE Z VALUES

1. Average percentages (weight) of oxides according to depth intervals.
   Example: Combine three A horizons for depth group 0-28 cm:
   SiO_2 (69.1 + 69.4 + 68.4) ÷ 3 = 68.97.
2. Convert oxide percentages to elemental percentages.
   Example: SiO_2 = 60.086; Si = 0.467, O = 0.533
   $Si_{(0-28)} = 68.97 \times 0.467$; $O_{(0-28)} = 68.97 \times 0.533$
3. Add all elemental percentages and loss percent.
   Example: ΣFe, Mn, Ti, Ca, K, S, P, Si, Al, Mg, Na, O = 100.44%
   $Loss_I$ = 8.50%
   Total = 100.44 + 8.50 = 108.94%
4. Divide all elements by their respective atomic weights.
   Example: Fe 5.02%/55.85 = 0.0899 (f-atom)
5. Normalize by dividing all f-atom values by Σf-atom.
   Example: Fe 0.0899/6.1401 = 0.0146 (Nf)
6. Multiply Nf values by elemental Z numbers.
   Example: Fe 0.0146 x 26 = 0.3796 (Zf)
7. Add all Nf values to obtain average Z value for the soil minerals.
8. Repeat the above procedure for humus and water.
9. Add average Z values of soil minerals, humus and water to obtain average Z value of the soil.

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APPENDIX B. FAO SOIL MAP NOMENCLATURE AND SOVIET EQUIVALENTS

The map symbols on the FAO Soil Map of the World consist of major soil categories (capital letter), sub-categories (lower case letter), associated soils and inclusions (numeral), soil texture (numerical suffix) (Ref. 3). An example would be Ch 22-2a: C = Chernozem, Ch = Typic Chernozem, 22 = associated soil [Ck (Calcic Chernozem)]; inclusion: none, 2 = medium texture, and a = dominant slope, level to gently undulating.

1. FAO SOIL UNIT DESCRIPTION

The map symbols designate the dominant soil unit (letters), followed by a figure (numerals) which refers to the descriptive legend on the back of the map in which full composition of the association is given. The associated soils are estimated to occupy at least 20 percent of the map unit. The inclusions are important soil units occupying <20 percent of the map unit.

2. FAO SOIL UNIT SUFFIXES

a. Numeral--Texture: relative proportions of clay (<2 µm), silt (2-50 µm) and sand (50-200 µm). Upper 30 cm of soil.

1 = Coarse. Sands, loamy sands and sandy loams with <18 percent clay and >65 percent sand.

2 = Medium. Sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams and clay loams with <35 percent clay and >65 percent sand; sand fraction may be as high as 82 percent if minimum of 18 percent clay present.

3 = Fine. Clays, silty clays, clay loams and silty clay loams with >35 percent clay.

b. Letter--Slope which dominates the area of the map unit.

a = Level to gently undulating: dominant slopes ranging between 0 percent and 8 percent.

b = Rolling to hilly: dominant slopes ranging between 8 percent and 30 percent.

c = Steeply dissected to mountainous: dominant slopes are >30 percent.

3. TABLES FOR FAO-SOVIET SOIL CORRELATION

The FAO soil categories for the USSR are listed in Table B1. Table B2 contains FAO soil map units for USSR strategic areas. The associated soils and inclusions for the USSR strategic areas are listed in Table B3. The FAO soil units and Soviet equivalents are listed in Table B4.

TABLE B1. SOIL CATEGORIES FOR FAO SOIL MAP OF THE WORLD
(SHEETS V-2, VIII-1, VIII-2, VIII-3)

A	Acrisols	Highly weathered soils with argillic horizons
T	Andosols	Volcanic ash with dark surfaces
Q	Arenosols	Soils formed from sand
B	Cambisols	Light color, structure or consistence change due to weathering
C	Chernozems	Black surface color, high humus under prairie vegetation
	Ferralsols	Sesquioxide-rich clay
J	Fluvisols	Water-deposited with little alteration
G	Gleysols	Mottled or reduced horizons due to wetness
M	Greyzems	Soils rich in organic matter having a grey color
O	Histosols	Organic soils
K	Kastanozems	Chestnut surface color, steppe vegetation
I	Lithosols	Shallow soils over hard rock
L	Luvisols	Medium- to high-base-status soils with argillic horizons
N	Nitosols	Low-CEC clay in argillic horizons
H	Phaeozems	Dark surface color, more bleached than kastanozems or chernozems
W	Planosols	Abrupt A-B horizon contact
P	Podzols	Light-colored alluvial horizon and subsoil accumulation of iron, aluminum, and humus
D	Podzoluvisols	Bleached horizons tonguing into argillic B horizons
U	Rankers	Thin soil over siliceous material
R	Regosols	Thin soil over unconsolidated material (regolith)
E	Rendzinas	Shallow soil over limestone
Z	Solonchaks	Soluble salt accumulation
S	Solonetz	High sodium content
V	Vertisols	Self-mulching, inverting soils, rich in montmorillonite clay
X	Xerosols	Dry soils of semiarid regions
Y	Yermosols	Desert soils

(Ref. 3)

TABLE B2. FAO SOIL MAP UNITS FOR USSR STRATEGIC AREAS

Area code	FAO soil map units (symbols)
ALDER	Mix of Lg1-2b, Gm 19-3a, Bd 3-2ab; linears of J2-2a, Gm 20-2/3a (drainages); perhaps C4-3a to south
BIRCH	Mostly I-Dd-Rd-2c; linears of C3-3a
CEDAR	Mostly I-Dd-Rd-2c; patches of Mg 4-3a, I-Mo-2c, Mg-2a
DOGWOOD	Mix of De9-2ab, Mg5-2ab, Mg2-2ab; perhaps some Je12-2a or Oe1-a
ELM	Mix of I-Mo-2c, I-Dd-2c; Cg6-3a, Cg2-3a; perhaps small patch of I-Gx-Rx-2c
FIR	Ck1-2a, Ch1-3a; linears of dunes/shifting sand
SPRUCE	Mostly K1-37-3a; two patches So1-3a; perhaps I-K-2c to south
HEMLOCK	Mostly Kh27-2a; perhaps some Kh25-2a
CYPRESS	Mostly Ck1-3a; patch of Ck4-3a; perhaps some Kh26-2a or Sm12-3a
JUNIPER	Mix of I-Mo-2c, I-Dd-2c; some Mo1-2a, I-Bh-2c, C113a
TAMARACK	Mostly De18-2a; some Lo89-2a; perhaps I-Bh-2c
LARCH	Mostly Ch22-2a; perhaps some Kh31-2a, Ch5-2a
MAPLE	Mostly De18-2a; perhaps patch of Od22-a
ASPEN	Mostly De18-2a; some De18-1a; perhaps patch of Lo89-2a
OAK	De18-2a
PINE	De18-2a; lesser De19-1a
SEQUOIA	Lg55-1a; patches Od22-a; some Je 87-2/3a; perhaps De18-2a
REDWOOD	Mostly Ch22-2a; perhaps some Ch5-2a

TABLE B3. FAO SOIL MAP UNITS WITH ASSOCIATED SOILS AND INCLUSIONS FOR USSR STRATEGIC AREAS

Soil unit	Associated soil	Inclusions	Soil unit	Associated soil	Inclusions
(MAP V-2)			(MAP VIII-2)		
Ch5-2a	---	H,L,R,So	Cg2-3a	Ck	---
Ch22-2a	Ck	---	Cg6-3a	Ch	---
De18-1a	---	---	De9-2ab	Gc,Ge	---
De18-2a	---	---	I-Mo-2c	---	---
De19-1a	Pg,Lg	Gh	I-Dd-2c	---	---
Je87-2/3a	G	J	Je12-2a	Ge,Gm	---
Lo89-2a	Mo	---	Mg2-2ab	Gx	---
Kh31-2a	---	Sm	Mg5-2ab	Dg,Gx	De,Gh
Od22-a	---	Pg,Gd	Oe1-a	---	---
Lg55-1a	Pl,Pg	Od	Rx-2c	Not listed	
(MAP VIII-1)			(MAP VIII-3)		
Ch1-3a	---	---	Bd3-2ab	---	---
Ck1-2a	---	---	C3-3a	Gx	---
Ck1-3a	---	---	C4-3a	Gm,Oe	---
Ck4-3a	Sm	---	Gm19-3a	---	Ge
Cl1-3a	---	---	Gm20-2/3a	Ge,Je	---
I-Bh-2c	---	---	I-Dd-Rd-2c	---	---
I-Dd-2c	---	---	I-Mo-2c	---	---
I-K-2c	---	---	J2-2a	G	---
I-Mo-2c	---	---	Lg1-2b	---	---
Kh26-2a	Gm,So,Zo	---	Mg2-2a	Gx	---
Kh27-2a	---	Gm	Mg4-3a	Gx,C	---
Kl37-3a	Gm	So			
Kh25-2a	So	---			
Mo1-2a	---	---			
SM12-3a	Sg	---			
So1-3a	---	---			

(Ref. 2)

TABLE B4. FAO SOIL UNIT NOMENCLATURE FOR USSR STRATEGIC AREAS

Soil symbol	FAO soil unit	Soviet equivalent
Bd	Dystric cambisols	(Infertile weathered material)
Bh	Humic cambisols	(Organic-rich weathered material)
C	Chernozems	Chernozems (black soils)
Cg	Glossic chernozems	Tonguing chernozems of Siberia
Ch	Haplic chernozems	Typic chernozems
Ck	Calcic chernozems	($CaCO_3$ accumulation)
Cl	Luvic chernozems	Podzolized chernozems
Dd	Dystric Podzoluvisols	Ortho-podzolic soils
De	Eutric podzoluvisols	Derno-podzolic soils
Dg	Gleyic podzoluvisols	Podzolic-gley soils
G	Gleysols	(mucky soil, excess water)
Gc	Calcaric gleysols	(mucky soil, excess water)
Gd	Dystric gleysols	(mucky soil, excess water)
Ge	Eutric gleysols	(mucky soil, excess water)
Gh	Humic gleysols	Meadow soils
Gm	Mollic gleysols	Meadow soils
Gx	Gelic gleysols	Tundra gleysoils
H	Phaeozems	(Organic matter, dark color)
I	Lithosols	Shallow mountain soils
J	Fluvisols	Alluvial soils
Je	Eutric fluvisols	(fertile alluvial soils)
K	Kastanozems	Chestnuts soils of dry steppes
Kh	Haplic kastanozems	(Simple normal horizon)
Kl	Luvic kastanozems	(Illuvial clay accumulation)
L	Luvisols	(Illuvial clay accumulation
Lg	Gleyic luvisols	Podzolic gleysoils
Lo	Orthic luvisols	Podzolized brown forest soils
Mg	Gleyic greyzems	Meadow gray forest soils
Mo	Orthic greyzems	Gray forest soils
Od	Dystric histosols	Bog soils (infertile)
Oe	Eutric histosols	Bog soils (fertile)
Pg	Gleyic podzols	Podzolic swampy humic-illuvial soils
Pl	Leptic podzols	(Shallow, undeveloped)
R	Regosols	(Regolith)
Rd	Dystric regosols	(Infertile regolith)
Rx	Gelic regosols	(Permafrost regolith)
Sg	Gleyic solonetz	Meadow solonetz
Sm	Mollic solonetz	Solonetz
So	Orthic solonetz	Solonetz
Zo	Orthic solonchaks	Solonchaks

(Ref. 3)

APPENDIX C. MICROELEMENT DATA ON USSR SOILS, SOIL-FORMING ROCKS, AND PLANTS

Quantitative data on microelements in USSR soils consisted primarily of means and variation limits of specific elements for the USSR, and values for a few specific regions (Ref. 8). From data presented in this report and other more fragmented data from a variety of sources, the combination of percentages and Z numbers appears insufficient to have an appreciable effect on the average Z values of the soils. Quantitative data was lacking or sparse on very high Z-number elements (e.g., uranium, lead, mercury) that might be associated with, or close to, ore deposits. The amounts of moderately high Z-number elements were very low.

The microelement contents of USSR soils and soil-forming rocks for molybdenum, zinc, copper, cobalt, manganese, and titanium are given in Tables C1 through C5. The content of microelements in soils, waters, and plants of the Orenburg region of the USSR is listed in Table C6 for lead, barium, strontium, zinc, copper, cobalt, nickel, manganese, chromium, and boron.

TABLE C1. ZINC CONTENT IN SOIL-FORMING ROCKS AND SOILS (Z=30)

Rocks, soils	Mean content (%)	Variation limits (%)	Number of analyses
Basalt	0.0112	0.0075-0.0130	3
Andesite	0.0063	0.0055-0.0070	2
Granite	0.0055	0.0015-0.0120	17
Loess & loess-like loam	0.0040	0.0017-0.0059	6
Blanket loam & clay	0.0030	0.0027-0.0034	2
Chernozem	0.0062	0.0024-0.0090	4
Tundra	0.0060	0.0053-0.0076	3
Krasnozem	0.0059	0.0046-0.0073	2
Chestnut	0.0053	---	1
Gray forest	0.0046	0.0028-0.0065	2
Sod-podzolic	0.0035	0.0020-0.0067	7
Serozem	0.0004	0.0003-0.0006	3

TABLE C1a. MOLYBDENUM CONTENT IN SOILS AND PLANTS (Z=42)

Chernozems	0.0046	0.00007-0.00086	24
Mountain soil	0.00040	0.00005-0.00120	5
Krasnozem	0.00026	0.00009-0.00040	3
Gray forest	0.00025	0.00017-0.00040	7
Podzolic	0.00021	0.00010-0.00040	6
Bog	0.00016	---	2
Serozem	0.00013	0.00007-0.00020	9
Chestnut	0.00011	0.00002-0.00020	9
Legumes (herbrous, seeds)	0.00040	0.00005-0.0020	56
Legumes (arboreal, seeds)	0.00040	0.00006-0.0010	27
Motley grass	0.00012	0.00003-0.0003	4
Cereals	0.00006	0.00002-0.0001	19

TABLE C2. COPPER CONTENT IN USSR SOIL-FORMING ROCKS, SOILS, AND PLANTS (Z=29)

Rocks, soils, plants	Mean content (%)	Variation limits (%)	Number of analyses
Basalt	0.0079	0.0016-0.028	14
Andesite	0.0032	0.0006-0.0083	9
Clay	0.0026	0.0002-0.006	45
Sandstone	0.0019	0.0002-0.006	6
Loess & loess-like loam	0.0018	0.0003-0.0089	11
Granite	0.0016	0.00003-0.0054	13
Blanket loam	0.0014	0.0003-0.0063	7
Boulder loam	0.0009	0.0008-0.0012	4
Limestone	0.009	0.0004-0.0024	11
Krasnozem & zheltozem	0.0076	0.0027-0.0014	9
Chernozem	0.0030	0.0007-0.0018	26
Saline	0.0027	0.0004-0.0042	7
Gray forest soils	0.0015	0.0005-0.0039	10
Sod-podzolic	0.0015	0.00001-0.0048	29
Bog	0.0011	0.0002-0.0037	57
Serozem	0.0011	0.0005-0.0020	11
Chestnut	0.0010	0.00006-0.0020	8
Tundra	0.0009	0.0002-0.0023	8
Legumes	0.0012	0.00044-0.0021	27
Motley grass	0.00062	0.0004-0.0014	7
Cereals	0.0006	0.0004-0.00075	4
Mosses & lichens	0.00058	0.00048-0.99968	3
Coniferous trees	0.00015	---	2

TABLE C3. COBALT CONTENT IN USSR SOIL-FORMING ROCKS, SOILS, AND PLANTS (Z=27)

Rocks, soils, plants (dry matter)	Mean content (%)	Variation limits (%)	Number of analyses
Basalt	0.00216	0.00028-0.0078	7
Clay	0.0014	0.00024-0.0068	33
Blanket loam	0.0011	0.00044-0.0027	6
Andesite	0.00098	0.00020-0.0015	3
Loess & loess-like loam	0.00085	0.00025-0.0012	6
Granite	0.00080	0.00061-0.0011	7
Sandstone	0.00080	0.00060-0.0016	13
Sand & sandy loam	0.00042	---	2
Limestone & dolomite	0.00018	0.00006-0.00028	10
Chestnut	0.00086	---	2
Krasnozem	0.00070	0.0004-0.0010	2
Chernozem	0.00061	0.00026-0.0013	8
Saline	0.00053	0.00017-0.00088	3
Sod-carbonate	0.00042	0.00009-0.00052	10
Gray forest	0.00039	0.00025-0.00080	5
Sod-podzolic	0.00031	0.000045-0.0014	15
Bog	0.00029	0.00008-0.00052	11
Serozem	0.00016	0.00016	3
Mosses & lichens	0.000045	0.000005-0.00019	7
Hay	0.000038	0.000008-0.000075	24
Legumes	0.000034	0.00002-0.0000056	22
Deciduous trees	0.000032	0.000015-0.000070	5
Coniferous trees	0.000025	---	2
Cereals	0.000018	0.000008-0.000033	15

TABLE C4. MANGANESE CONTENT IN USSR SOIL-FORMING ROCKS AND SOILS (Z=25)

Rock or soil	Mean manganese content (%)	Variation limits (%)	Number of analyses
Basalt	0.15	0.10-0.22	10
Loess	0.86	0.04-0.38	25
Granite	0.072	0.02-0.10	5
Clay	0.065	0.023-0.12	9
Limestone	0.059	0.04-0.5	2
Sand	0.020	0.002-0.50	4
Krasnozem	0.144	0.02-0.40	16
Clayey podzolic	0.127	0.023-0.72	50
Mountain soils	0.117	0.01-0.65	34
Gray forest soil	0.100	0.0149-0.398	67
Chestnut	0.096	0.06-0.127	12
Chernozem	0.084	0.02-0.56	83
Serozem	0.079	0.031-0.38	71
Saline	0.073	0.04-0.164	32
Sod-carbonate soils	0.066	0.013-0.24	13
Bog	0.033	0.005-0.10	14
Sandy podzolic	0.017	0.004-0.033	14

TABLE C5. TITANIUM CONTENT IN USSR SOIL-FORMING ROCKS AND SOILS (Z=22)

Rock or soil	Mean titanium content (%)	Variation limits (%)	Number of analyses
Basalt	1.30	0.39-3.78	16
Clay	0.32	0.04-0.66	31
Loess	0.28	0.13-0.80	36
Granite	0.20	0.04-0.54	10
Limestone	0.16	0.10-0.64	22
Sand	0.11	0.007-0.30	15
Krasnozem	0.60	0.17-1.27	12
Gray forest	0.47	0.40-0.56	9
Podzolic	0.43	0.005-0.97	28
Chernozem	0.40	0.32-0.56	25
Mountain soil	0.33	0.01-0.66	16
Saline	0.31	0.12-0.58	3
Bog	0.26	0.14-0.98	9
Serozem	0.20	0.05-0.68	36

TABLE C6. CONTENT OF MICROELEMENTS IN SOILS, WATERS, AND PLANTS OF THE ORENBURG REGION, USSR

Microelement	Atomic weight	Soil (%) air-dry	Water (%) dry residue	Plants (%) ash	Soils of central Russian plain	Element symbol	Total (%)
Lead	207.19	.004	.003	.009	.001	Pb	.016
Barium	137.34	.04	.006	.03	.05	Ba	.076
Strontium	87.62	.01	.06	.009	.03	Sr	.079
Zinc	65.37	.007	.03	.03	.005	Zn	.067
Copper	63.54	.003	.02	.009	.002	Cu	.032
Cobalt	58.93	.002	.001	.001	.001	Co	.004
Nickel	58.71	.009	.003	.008	.004	Ni	.020
Manganese	54.94	.02	.002	.03	.085	Mn	.052
Chromium	52.00	.03	.02	.009	.02	Cr	.059
Boron	10.81	.005	.005	.003	.001	B	.011

APPENDIX D. ELEMENTAL COMPOSITION OF SOILS IN USSR STRATEGIC AREAS

The bulk chemical compositions, plus humus and hydroscopic water data, were obtained from the Agrochemistry of the Soils of the USSR (Vols. 2, 4, 6, and 8-14) (Ref. 1). Volumes 1, 8, 13, and 14 are in Russian and the pertinent material had to be translated. This set of volumes is a compilation from many Soviet sources and thus the content and format varies considerably. The soil analyses selected for use in this study were based on the FAO soil maps (Refs. 2 and 3) and the Agrochemistry volumes. The elemental composition of these soils is presented in Tables D1 through D22.

TABLE D1. ALDER AREA--ELEMENTAL COMPOSITION OF BROWN FOREST GRAY PODZOLIZED SOILS

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-30	O	48.93	Fe	3.29
	Si	32.51	Mn	0.09
	Al	9.02	Ca	2.20
	Fe	3.29	K	0.85
	Ca	2.20	S	0.30
	Mg	1.02	P	0.05
	K	0.85	Si	32.51
	Na	0.68	Al	9.02
	S	0.20	Mg	1.02
	Mn	0.09	Na	0.68
	P	0.05	O	48.93
	Loss$_I$	2.56		
55-130	O	47.83	Fe	4.47
	Si	30.56	Mn	0.05
	Al	10.71	Ca	1.15
	Fe	4.47	K	1.07
	Ca	1.15	S	0.03
	K	1.07	P	0.03
	Mg	0.75	Si	30.56
	Na	0.65	Al	10.71
	Mn	0.05	Mg	0.75
	S	0.03	Na	0.65
	P	0.03	O	47.83

TABLE D2. ALDER AREA--ELEMENTAL COMPOSITION OF BROWN FOREST PODZOLIZED SOIL

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-34	O	49.45	Fe	2.42
	Si	34.93	Mn	0.63
	Al	6.81	Ca	1.59
	Fe	2.42	K	1.62
	K	1.62	S	0.21
	Ca	1.59	P	0.06
	Na	1.07	Si	34.93
	Mg	0.87	Al	6.81
	Mn	0.63	Mg	0.87
	S	0.21	Na	1.07
	P	0.06	O	49.45
	Loss$_I$	8.49		
40-70	O	51.00	Fe	1.53
	Si	38.44	Mn	tr
	Al	5.89	Ca	0.51
	Fe	1.53	K	0.81
	K	0.81	S	0.35
	Ca	0.51	P	0.01
	Mg	0.41	Si	38.44
	S	0.35	Al	5.89
	Na	0.13	Mg	0.41
	P	0.01	Na	0.13
	Mn	tr	O	51.00
	Loss$_I$	3.30		
160-170	O	51.05	Fe	1.08
	Si	41.14	Mn	tr
	Al	2.85	Ca	0.42
	K	1.73	K	1.73
	Fe	1.08	S	0.22
	Ca	0.42	P	tr
	Na	0.25	Si	41.14
	Mg	0.24	Al	2.85
	S	0.22	Mg	0.24
	P	tr	Na	0.25
	Mn	tr	O	51.05
	Loss$_I$	1.58		

TABLE D3. ALDER AREA--ELEMENTAL COMPOSITION OF DEEP MEADOW CHERNOZEM-LIKE SOIL

	In order of abundance		In order of atomic weight	
Depth (cm)	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-36	O	49.02	Fe	3.94
	Si	31.96	Mn	0.10
	Al	10.30	Ca	1.17
	Fe	3.94	K	1.66
	K	1.66	P	0.0
	Ca	1.17	Si	31.96
	Na	1.11	Al	10.30
	Mg	0.58	Mg	0.58
	Mn	0.10	Na	1.11
	P	0.09	O	49.02
	Loss$_I$	9.17		
44-144	O	49.12	Fe	3.96
	Si	32.06	Mn	0.08
	Al	10.54	Ca	0.96
	Fe	3.96	K	1.54
	K	1.54	P	0.04
	Ca	0.96	Si	32.06
	Na	0.94	Al	10.54
	Mg	0.57	Mg	0.57
	Mn	0.08	Na	0.94
	P	0.04	O	49.12
	Loss$_I$	3.82		

TABLE D4. BIRCH AREA--ELEMENTAL COMPOSITION OF CHERNOZEMS

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-30	O	48.88	Fe	4.50
	Si	32.62	Mn	0.09
	Al	7.91	Ca	1.56
	Fe	4.50	K	1.15
	Ca	1.56	S	0.50
	K	1.15	P	0.07
	Mg	0.96	Si	32.62
	Mn	0.09	Al	7.91
	Na	0.73	Mg	0.96
	S	0.50	Na	0.73
	P	0.07	O	48.88
	$Loss_I$	4.65		
40-150	O	50.20	Fe	1.50
	Si	37.38	Mn	0.01
	Al	5.45	Ca	1.13
	Fe	1.50	K	1.03
	Ca	1.13	S	0.36
	K	1.03	P	0.11
	Mg	0.71	Si	37.38
	Na	0.66	Al	5.45
	S	0.36	Mg	0.71
	P	0.11	Na	0.66
	Mn	0.01	O	50.20
	$Loss_I$	0.32		

TABLE D5. CYPRESS AREA--ELEMENTAL COMPOSITION OF SOUTHERN CHERNOZEM (Y-B CLAY BASE)

	In order of abundance		In order of atomic weight	
Depth (cm)	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-27	O	44.28	Fe	3.96
	Si	25.03	Ca	7.48
	Al	8.77	Si	25.03
	Ca	7.48	Al	8.77
	Fe	3.96	Mg	1.88
	Mg	1.88	O	44.28
	Loss_{I}	5.40		
40-150	O	46.53	Fe	4.03
	Si	25.10	Ca	9.91
	Ca	9.91	Si	25.10
	Al	8.91	Al	8.91
	Fe	4.03	Mg	1.54
	Mg	1.54	O	46.53
	Loss_{I}	1.20		

TABLE D6. CYPRESS AREA--ELEMENTAL COMPOSITION OF SOUTHERN CHERNOZEM (K CLAY BASE)

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-20	O	44.02	Fe	3.15
	Si	34.37	Ca	0.24
	Al	3.60	Si	34.37
	Fe	3.15	Al	3.60
	Ca	0.24	Mg	0.21
	Mg	0.21	O	44.02
	Loss_I	4.80		
40-90	O	46.62	Fe	1.92
	Si	28.95	Ca	1.06
	Al	13.41	Si	28.95
	Fe	1.92	Al	13.41
	Ca	1.06	Mg	0.18
	Mg	0.18	O	46.62
	Loss_I	0.90		

TABLE D7. DOGWOOD AREA--ELEMENTAL COMPOSITION OF LIGHT-GRAY STRONGLY PODZOLIZED SOIL (GRAY FOREST)

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-32	O	50.01	Fe	1.50
	Si	35.40	Ca	0.71
	Al	8.62	K	1.39
	Fe	1.50	S	0.02
	K	1.39	P	0.04
	Na	0.91	Si	35.40
	Ca	0.71	A	8.62
	Mg	0.54	Mg	0.54
	P	0.04	Na	0.91
	S	0.02	O	50.01
	Loss$_I$	6.50		
45-130	O	48.90	Fe	3.01
	Si	32.41	Ca	0.93
	Al	10.24	K	1.54
	Fe	3.01	S	0.04
	K	1.54	P	0.02
	Mg	0.97	Si	32.41
	Ca	0.93	Al	10.24
	Na	0.38	Mg	0.97
	S	0.04	Na	0.38
	P	0.02	O	48.90
	Loss$_I$	4.15		
195-205	O	49.18	Fe	3.57
	Si	32.88	Ca	0.91
	Al	10.05	Si	32.88
	Fe	3.57	Al	10.05
	Mg	1.24	Mg	1.24
	Ca	0.91	O	49.18
	Loss$_I$	4.30		

TABLE D8. DOGWOOD AREA--ELEMENTAL COMPOSITION OF DARK-GRAY WEAKLY PODZOLIZED SOIL (GRAY FOREST)

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-28	O	49.02	Fe	5.02
	Si	32.21	Mn	0.13
	Al	8.31	Ti	0.60
	Fe	5.02	Ca	1.36
	Mg	1.39	K	1.36
	Ca	1.36	P	0.09
	Na	0.81	Si	32.21
	Ti	0.60	Al	8.31
	S	0.15	Mg	1.39
	Mn	0.13	Na	0.81
	P	0.09	O	49.02
	Loss$_I$	8.53		
55-90	O	48.34	Fe	5.64
	Si	31.34	Mn	0.12
	Al	8.44	Ti	0.66
	Fe	5.64	Ca	1.28
	Mg	1.58	K	0.95
	Ca	1.28	S	0.08
	K	0.95	P	0.07
	Na	0.75	Si	31.34
	Ti	0.66	Al	8.44
	Mn	0.12	Mg	1.58
	S	0.08	Na	0.75
	P	0.07	O	48.34
	Loss$_I$	4.45		
160-170	O	48.51	Fe	4.97
	Si	31.34	Mn	0.12
	Al	8.89	Ti	0.60
	Fe	4.97	Ca	1.37
	Mg	1.62	K	1.24
	Ca	1.37	S	0.04
	K	1.24	P	0.07
	Na	0.79	Si	31.34
	Ti	0.60	Al	8.89
	Mn	0.12	Mg	1.62
	P	0.07	Na	0.79
	S	0.04	O	48.51
	Loss$_I$	5.30		

TABLE D9. HEMLOCK AREA--ELEMENTAL COMPOSITION OF CHESTNUT NORMAL LOAMY SOIL

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-28	O	47.90	Fe	3.15
	Si	32.50	Mn	0.09
	Al	7.9	Ca	3.49
	Ca	3.49	K	1.58
	Fe	3.15	S	0.07
	K	1.58	Si	32.50
	H	0.64	Al	7.93
	Na	0.56	Mg	0.38
	Mg	0.38	Na	0.56
	Mn	0.09	O	47.90
	P	0.08	H	0.64
	S	0.07		
	Loss$_I$	6.44		
100-150	O	50.19	Fe	2.19
	Si	36.08	Mn	0.05
	Al	5.48	Ca	1.23
	Fe	2.19	K	1.33
	K	1.33	S	0.16
	Ca	1.23	Si	36.08
	H	1.00	Al	5.48
	Na	0.68	Mg	0.37
	Mg	0.37	Na	0.68
	S	0.16	O	48.60
	P	0.09	H	1.00
	Mn	0.05		
	Loss$_I$	10.00		

TABLE D10. JUNIPER AREA--ELEMENTAL COMPOSITION OF STRONGLY PODZOLIC SOIL

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
AA-AB horizons	O	48.32	Fe	4.80
	Si	32.62	Ca	1.99
	Al	7.08	K	1.45
	Fe	4.80	S	0.05
	Ca	1.99	P	0.11
	Mg	1.59	Si	32.62
	K	1.45	Al	7.08
	Na	1.26	Mg	1.59
	P	0.11	Na	1.26
	S	0.05	O	48.32
	Loss$_I$	5.60		
B_1-B horizons	O	47.76	Fe	6.03
	Si	29.60	Ca	2.71
	Al	8.84	K	1.29
	Fe	6.03	S	0.14
	Ca	2.71	P	0.08
	Mg	2.15	Si	29.70
	K	1.29	Al	8.84
	Na	1.08	Mg	2.15
	S	0.14	Na	1.08
	P	0.08	O	47.76
	Loss$_I$	3.50		

TABLE D11. JUNIPER AREA--ELEMENTAL COMPOSITION OF PODZOLIZED CHERNOZEM

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-43	O	44.75	Fe	2.86
	Si	29.87	Ca	0.95
	Al	8.69	K	1.00
	Fe	2.86	S	0.11
	Na	1.12	P	0.01
	K	1.00	Si	29.87
	Ca	0.95	Al	8.69
	Mg	0.91	Mg	0.91
	S	0.11	Na	1.12
	P	0.01	O	44.75
	Loss_I	10.67		
62-105	O	45.27	Fe	3.13
	Si	29.54	Ca	2.65
	Al	9.05	K	0.76
	Fe	3.13	S	0.12
	Ca	2.65	P	0.00
	Mg	0.93	Si	29.54
	K	0.76	Al	9.05
	Na	0.61	Mg	0.93
	S	0.12	Na	0.61
	P	0.00	O	45.27
	Loss_I	7.30		

TABLE D12. TAMARACK AREA--ELEMENTAL COMPOSITION OF SOD-MEDIUM PODZOLIC HEAVY LOAMY SOIL

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-31	O	44.12	Fe	4.84
	Si	32.32	Ca	0.94
	Fe	4.84	P	0.02
	Al	4.55	Si	32.32
	Mg	1.09	Al	4.55
	Ca	0.94	Mg	1.09
	N	0.18	O	44.12
	P	0.02	N	0.18
	Humus	2.60		
56-120	O	43.58	Fe	5.71
	Si	29.73	Ca	2.61
	Al	5.86	P	0.01
	Fe	5.71	Si	29.73
	Ca	2.61	Al	5.86
	Mg	1.41	Mg	1.41
	N	0.04	O	43.58
	P	0.01	N	0.04
	Humus	0.60		

TABLE D13. TAMARACK AREA--ELEMENTAL COMPOSITION OF GRAY FOREST LOAMY SOIL

	In order of abundance		In order of atomic weight	
Depth (cm)	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
2-37	O	48.64	Fe	4.74
	Si	34.40	Mn	1.53
	Al	6.70	Ca	0.89
	Fe	4.74	P	0.07
	Mn	1.53	Si	34.40
	Ca	0.89	Al	6.70
	Mg	0.76	Mg	0.76
	N	0.22	O	48.64
	P	0.07	N	0.22
	Loss$_I$	3.20		
61-91	O	49.53	Fe	6.17
	Si	33.25	Mn	1.47
	Al	8.31	Ca	0.91
	Fe	6.17	P	0.04
	Mn	1.47	Si	33.25
	Mg	1.04	Al	8.31
	Ca	0.91	Mg	1.04
	P	0.04	O	49.53
	N	0.03	N	0.03
	Loss$_I$	0.60		
153-163	O	48.95	Fe	6.70
	Si	31.99	Mn	1.84
	Al	7.66	Ca	2.15
	Fe	6.70	P	0.43
	Ca	2.15	Si	31.99
	Mn	1.84	Al	7.66
	Mg	1.21	Mg	1.21
	P	0.43	O	48.95
	Loss$_I$	0.70		

TABLE D14. LARCH AREA--ELEMENTAL COMPOSITION OF TYPICAL CHERNOZEM

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-38	O	42.48	Fe	3.16
	Si	27.96	Mn	0.05
	Al	8.17	Ti	0.36
	Fe	3.16	Ca	2.31
	Ca	2.31	K	0.60
	K	0.60	S	0.11
	Mg	0.44	P	0.07
	Ti	0.36	Si	27.96
	Na	0.29	Al	8.17
	S	0.11	Mg	0.44
	P	0.07	Na	0.29
	Mn	0.05	O	42.48
	Loss$_I$	14.77		
50-105	O	44.52	Fe	3.11
	Si	28.88	Mn	0.05
	Al	8.49	Ti	0.35
	Ca	3.69	Ca	3.69
	Fe	3.11	K	0.72
	Mg	0.80	S	0.08
	K	0.72	P	0.04
	Ti	0.35	Si	28.88
	Na	0.28	Al	8.49
	S	0.08	Mg	0.80
	Mn	0.05	Na	0.28
	P	0.04	O	44.52

TABLE D15. MAPLE AREA--ELEMENTAL COMPOSITION OF PODZOLIC CLAY

	In order of abundance		In order of atomic weight	
Depth (cm)	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
8-40	O	49.68	Fe	1.86
	Si	36.49	Mn	tr
	Al	7.15	Ca	0.99
	Fe	1.86	P	0.03
	Ca	0.99	Si	36.49
	Mg	0.68	Al	7.15
	H	0.27	Mg	0.68
	Mn	0.04	O	49.68
	P	0.03	H	0.27
	Loss$_I$	2.65		
45-150	O	49.42	Fe	3.14
	Si	33.95	Mn	0.03
	Al	8.60	Ca	1.73
	Fe	3.14	P	0.09
	Ca	1.73	Si	33.95
	Mg	1.37	Al	8.60
	H	0.49	Mg	1.37
	P	0.09	O	49.42
	Mn	0.03	H	0.49
	Loss$_I$	4.89		
8-40 fine fraction <0.0001 mm	O	46.56	Fe	7.17
	Si	26.99	Mn	0.05
	Al	13.07	Ca	0.63
	Fe	7.17	P	0.02
	Mg	1.16	Si	26.99
	H	0.77	Al	13.07
	Ca	0.63	Mg	1.16
	Mn	0.05	O	46.56
	P	0.02	H	0.77
	Loss$_I$			
45-150	O	45.51	Fe	7.36
	Si	26.76	Mn	0.03
	Al	12.57	Ca	0.29
	Fe	7.36	P	0.01
	H	0.76	Si	26.76
	Mg	0.75	Al	12.57
	Ca	0.29	Mg	0.75
	Mn	0.03	O	45.54
	P	0.01	H	0.76
	Loss$_I$	7.59		

TABLE D16. OAK AREA--ELEMENTAL COMPOSITION OF SOD MEDIUM PODZOLIC HEAVY CLAY

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
1-40	O	50.41	Fe	1.71
	Si	37.06	Mn	0.09
	Al	6.79	Ca	2.40
	Ca	2.40	P	0.06
	Fe	1.71	Si	37.06
	H	0.49	Al	6.79
	Mg	0.41	Mg	0.41
	Mn	0.09	O	50.41
	P	0.06	H	0.49
	Loss$_I$	4.90		
60-108	O	50.12	Fe	2.71
	Si	35.47	Mn	0.05
	Al	8.22	Ca	1.59
	Fe	2.71	P	0.15
	Ca	1.59	Si	35.47
	Mg	0.57	Al	8.22
	H	0.39	Mg	0.57
	P	0.15	O	50.12
	Mn	0.05	H	0.39
	Loss$_I$	3.86		
1-40 Fraction <0.0001 mm	Al	46.71	Fe	6.91
	Si	26.87	Mn	0.07
	Al	13.16	Ca	0.47
	Fe	6.91	P	0.01
	Mg	1.74	Si	26.87
	H	0.76	Al	13.16
	Ca	0.47	Mg	1.74
	Mn	0.07	O	46.71
	P	0.01	H	0.76
	Loss$_I$	7.58		
60-108	O	44.92	Fe	7.89
	Si	25.03	Mn	0.04
	Al	13.18	Ca	0.36
	Fe	7.89	P	0.01
	Mg	1.61	Si	25.03
	H	0.83	Al	13.18
	Ca	0.36	Mg	1.61
	Mn	0.04	O	44.92
	P	0.01	H	0.83
	Loss$_I$	8.26		

TABLE D17. OAK AREA--ELEMENTAL COMPOSITION OF SOD PODZOLIC CLAY (GLACIAL BASE)

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
8-30	O	50.97	Fe	1.87
	Si	40.19	Ca	0.68
	Al	4.32	P	0.01
	Fe	1.87	Si	40.19
	Ca	0.68	Al	4.32
	H	0.40	Mg	0.25
	Mg	0.25	O	50.97
	P	0.01	H	0.40
	Loss$_I$	3.96		
50-150	O	50.24	Fe	2.52
	Si	36.96	Ca	0.92
	Al	7.13	P	0.02
	Fe	2.52	Si	36.96
	Ca	0.92	Al	7.13
	H	0.42	Mg	0.35
	Mg	0.35	O	50.24
	P	0.02	H	0.42
	Loss$_I$	4.25		
Fine fraction 8-30	O	47.36	Fe	6.67
	Si	26.86	Ca	0.41
	Al	14.50	P	0.07
	Fe	6.67	Si	26.86
	H	1.28	Al	14.50
	Mg	1.05	Mg	1.05
	Ca	0.41	O	47.36
	P	0.07	H	1.28
	Loss$_I$	12.83		
50-150	O	47.50	Fe	8.30
	Si	25.71	Ca	0.68
	Al	15.33	P	0.04
	Fe	8.30	Si	25.71
	H	1.26	Al	15.33
	Mg	0.96	Mg	0.96
	Ca	0.68	O	47.50
	P	0.04	H	1.26
	Loss$_I$	12.55		

TABLE D18. OAK AREA--ELEMENTAL COMPOSITION OF MARSHY SOILS

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-35	O	48.37	Fe	3.60
	Si	34.26	Ca	0.64
	Al	8.00	P	0.02
	Fe	3.60	Si	34.26
	Ca	0.69	Al	8.00
	Mg	0.45	Mg	0.45
	P	0.02	O	48.37
55-135	O	41.93	Fe	2.16
	Si	25.85	Ca	2.81
	Al	10.64	P	0.02
	Ca	2.81	Si	25.85
	Fe	2.16	Al	10.64
	Mg	1.36	Mg	1.36
	P	0.02	O	41.93

TABLE D19. PINE AREA--ELEMENTAL COMPOSITION OF BOG SOILS (30)

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
5-35	O	48.43	Fe	3.66
	Si	34.26	Ca	0.63
	Al	8.00	P	0.02
	Fe	3.66	Si	34.26
	Ca	0.63	Al	8.00
	Mg	0.54	Mg	0.54
	P	0.02	O	48.43
55-135	O	43.73	Fe	6.34
	Si	25.85	Ca	2.81
	Al	10.64	P	0.02
	Fe	6.34	Si	25.85
	Ca	2.81	Al	10.64
	Mg	1.36	Mg	1.36
	P	0.02	O	43.73

TABLE D20. PINE AREA--ELEMENTAL COMPOSITION OF BOG SOILS (59)

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-35	O	47.59	Fe	1.21
	Si	39.33	Ca	0.32
	Al	2.26	Si	39.33
	Fe	1.21	Al	2.26
	Ca	0.32	Mg	0.07
	Mg	0.07	O	47.59
45-80	O	52.24	Fe	0.49
	Si	44.23	Ca	0.16
	Al	1.64	Si	44.23
	Fe	0.49	Al	1.64
	Ca	0.16	Mg	0.05
	Mg	0.05	O	52.24

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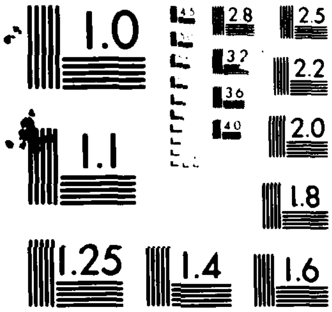

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TABLE D21. SEQUOIA AREA--ELEMENTAL COMPOSITION OF SODDY-MEDIUM PODZOLIC SANDY LOAM SOIL

Depth (cm)	In order of abundance		In order of atomic weight	
	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
0-40	O	51.59	Fe	0.29
	Si	43.70	Mn	0.24
	Al	0.95	Ca	0.43
	K	0.92	K	0.92
	Ca	0.43	P	0.04
	Fe	0.29	Si	43.70
	Mg	0.25	Al	0.95
	Mn	0.24	Mg	0.25
	N	0.18	O	51.59
	P	0.04	N	0.18
50-110	O	52.14	Fe	0.70
	Si	43.11	Mn	0.01
	Al	2.31	Ca	0.44
	K	0.83	K	0.83
	Fe	0.70	P	0.04
	Ca	0.44	Si	43.11
	N	0.22	Al	2.31
	Mg	0.08	Mg	0.08
	P	0.04	O	52.14
	Mn	0.01	N	0.22
0-40 Silt fraction	O	48.87	Fe	4.22
	Si	27.80	Mn	0.44
	Al	13.71	Ca	0.34
	Fe	4.22	K	3.07
	K	3.07	P	0.48
	N	1.65	Si	27.80
	Mg	1.01	Al	13.71
	P	0.48	Mg	1.01
	Mn	0.44	O	48.87
	Ca	0.34	N	1.65
50-100	O	47.15	Fe	6.14
	Si	25.25	Mn	0.07
	Al	14.52	Ca	0.11
	Fe	6.14	K	3.00
	K	3.00	P	0.39
	N	1.75	Si	25.25
	Mg	0.88	Al	14.52
	P	0.39	Mg	0.88
	Ca	0.11	O	47.15
	Mn	0.07	N	1.75

TABLE D22. REDWOOD AREA--ELEMENTAL COMPOSITION OF REGRADED HEAVY ARGILLACEOUS CHERNOZEMS

	In order of abundance		In order of atomic weight	
Depth (cm)	Element symbol	Percentage (wt)	Element symbol	Percentage (wt)
Arable layer (topmost)	O	46.89	Fe	2.29
	Si	33.19	Ti	1.06
	Al	6.14	Ca	3.23
	Fe	2.29	Si	33.19
	Ti	1.06	Al	6.14
	Ca	3.23	Mg	0.87
	Mg	0.87	O	46.89
	Loss$_T$	8.47		

GLOSSARY OF TERMS IN SOIL SCIENCE*

absorbed water. Water held mechanically in a soil mass and having physical properties similar to ordinary water at the same temperature and pressure.

adsorbed water. Water held in a soil mass by physicochemical forces and having physical properties substantially different from absorbed water or chemically combined water at the same temperature and pressure.

adsorption complex. The groups of substances in the soil capable of adsorbing other materials. Organic and inorganic colloidal substances form the greater part of the adsorption complex. The noncolloidal materials, such as silt and sand, exhibit adsorption to a much lesser extent than the colloidal materials.

air-dry. (a) The state of dryness of a soil at equilibrium with the moisture content of the surrounding atmosphere. The moisture content depends on the relative humidity and the temperature of the surrounding atmosphere. (b) To allow to reach equilibrium in moisture content with the surrounding atmosphere.

alluvium. Material such as clay, silt, sand, and gravel deposited by modern rivers and streams.

association, soil. A natural grouping of soil associates based on similarities in climatic or physiographic factors and soil parent materials. It may include a number of soil associates provided that they are all present in significant proportions.

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*Source: Glossary of Terms in Soil Science, Canada, Department of Agriculture, Publication 1459, Revised 1976, 44 p.

azonal soil. Soil without distinct genetic horizons.

bedrock. The solid rock that underlies soil and the regolith or that is exposed at the surface.

bog. Permanently wet land having low bearing strength.

bulk density, soil (apparent density). The mass of dry soil per unit bulk volume. The bulk volume is determined before the soil is dried to constant weight at 105°C.

bulk specific gravity (apparent specific gravity). The ratio of the bulk density of a soil to the mass of a unit volume of water.

bulk volume. The volume, including the solids and the pores, of an arbitrary soil mass.

calcareous soil. Soil containing sufficient calcium carbonate, commonly with magnesium carbonate, to effervesce visibly when treated with cold 0.1N hydrochloric acid.

caliche. A layer near the surface, more or less cemented by secondary carbonates of calcium or magnesium precipitated from the soil solution. It may be a soft thin soil horizon, a hard thick bed just beneath the solum, or a surface layer exposed by erosion.

chemistry, soil. The division of soil science dealing with the chemical constitution, properties and reactions of soils.

Chernozemic. An order of soils that have developed under xerophytic or mesophytic grasses and forbs, or under grassland forest transition vegetation, in cool to cold, subarid to subhumid climates. The soils have a dark-colored surface (Ah, Ahe, or Ap) horizon and a B or C horizon, or both, of high base saturation.

classification, soil. The systematic arrangement of soils into categories on the basis of their characteristics. Broad groupings are made on the basis of general characteristics, and subdivisions on the basis of more detailed differences in specific properties.

Clay. (a) As a particle-size term: a size fraction less than 0.002 mm in equivalent diameter, or some other limit (geologists and engineers). (b) As a rock term: a natural, earthy, fine grained material that develops plasticity with a small amount of water. (c) As a soil term: a textural class. (d) As a soil separate: a material usually consisting largely of clay minerals but commonly also of amorphous free oxides and primary minerals.

clay loam. Soil material that contains 27% to 40% clay and 20% to 45% sand.

degradation. The changing of a soil to a more highly leached and weathered state, usually accompanied by morphological changes such as the development of an eluviated, light-colored A (Ae) horizon.

eluviation. The transportation of soil material in suspension or in solution within the soil by the downward or lateral movement of water.

field capacity. The percentage of water remaining in the soil 2 or 3 days after the soil has been saturated and free drainage has practically ceased. The percentage may be expressed in terms of weight or volume.

fluvial deposits. All sediments, past and present, deposited by flowing water, including glaciofluvial deposits.

gleysation. A soil-forming process, operating under poor drainage conditions, which results in the reduction of iron and other elements, and in gray colors and mottles.

Gleysol. A great group of soils in the Gleysolic order. A thin (<8 cm or 3 in) Ah horizon is underlain by mottled gray or brownish gleyed material, or the soil has no Ah horizon. Up to 40 cm (16 in) of mixed peat (bulk density 0.1 or more) or 60 cm (24 in) of fibric moss peat (bulk density <0.1) may occur on the surface.

ground water. Water that is passing through or standing in the soil and the underlying strata. It is free to move by gravity.

heavy soil. A soil having a high content of the five separates, particularly clay, or a soil having a high drawbar pull and therefore hard to cultivate.

horizon, soil. A layer of soil or soil material approximately parallel to the land surface; it differs from adjacent genetically related layers in properties such as color, structure, texture, consistence, and chemical, biological, and mineralogical composition. A list of the designations follows:

(1) Organic layers contain 17% or more organic carbon.

(2) Mineral horizons and layers contain <17% organic carbon.

A. A mineral horizon formed at or near the surface in the zone of removal of materials in solution and suspension, or maximum in situ accumulation of organic carbon, or both.

B. A mineral horizon characterized by one or more of the following:

(a) An enrichment in silicate clay, iron, aluminum, or humus.

(b) A prismatic or columnar structure that exhibits pronounced coatings or stainings associated with significant amounts of exchangeable sodium.

(c) An alteration by hydrolysis, reduction, or oxidation to give a change in color or structure from the horizons above or below, or both.

C. A mineral horizon comparatively unaffected by the pedogenic processes operated in A and B, except gleying, and the accumulation of carbonates and more soluble salts.

D. Underlying consolidated bedrock that is too hard to break with the hands or to dig when moist.

Numerals are suffixed to horizon designations to indicate unconsolidated lithologic discontinuities in the profile. Lower case suffixes include (partial list):

ar - Arable layer (usually uppermost 30 cm).
g - A horizon characterized by gray colors, or prominent mottling indicated by permanent or periodic intense reduction, or both.
h - A horizon enriched with organic matter.
k - Presence of carbonate.
p - A layer disturbed by man's activities, e.g., Ap.

Humic Gleysol. A great group of soils in the Gleysolic order. A dark-colored A (Ah or Ap) horizon more than 8 cm (3 in) thick is underlain by mottled gray or brownish gleyed mineral material. It may have up to 40 cm (16 in) of mixed peat (bulk density 0.1 or more) or up to 60 cm (24 in) of fibric moss peat (bulk density <0.1) on the surface. This group includes soils formerly classified as Meadow or Dark Gray Gleysolic.

humic layer. A layer of highly decomposed organic soil material containing little fiber.

humus. (a) The fraction of the soil organic matter that remains after most of the added plant and animal residues have decomposed. It is usually dark colored. (b) Humus also is used in a broader sense to designate the humus forms referred to as forest humus. (c) All the dead organic material on and in the soil that undergoes continuous breakdown, change, and synthesis.

Hydroscopic water. Water adsorbed by a dry soil from an atmosphere of high relative humidity; water lost from an air-dry soil when it is heated to 105°C; water held by the soil when it is at equilibrium with an atmosphere of a specified relative humidity at a specified temperature, usually 98% relative humidity at 25°C.

illuvial horizon. A soil horizon in which material carried from an overlying layer has been precipitated from solution or deposited from suspension as a layer of accumulation.

illuviation. The process of depositing soil material removed from one horizon in the soil to another usually from an upper to a lower horizon in the soil profile. Illuviated substances include silicate clay, hydrous oxides of iron and aluminum and organic matter.

immature soil. A soil having indistinct or only slightly developed horizons.

intrazonal soil. A soil having a morphology that shows the influence of some local factor of relief, present material, or age, rather than of climate and vegetation.

leaching. The removal from the soil of materials in solution.

loamy. Intermediate in texture and properties between fine-textured and coarse-textured soils.

Luvisolic. An order of soils that have eluvial (Ae) horizons and illuvial (Bt) horizons in which silicate clay is the main accumulation product. The soils developed under forest or forest-grassland transition in a moderate to cool climate.

macronutrient. A chemical element necessary in large amounts, usually >1 ppm in the plant, for the growth of plants and usually applied artificially in fertilizer or liming materials.

mature soil. A soil having well-developed soil horizons produced by the natural processes of soil formation.

micronutrient (trace element). A chemical element necessary in only small amounts, usually <1 ppm in the plant, for the growth of plants and the health of animals. Examples are boron, molybdenum, copper, iron, manganese, and zinc.

moisture, soil. Water contained in the soil.

moisture tension, soil. In soils partially saturated with water there is moisture tension, which is equal in magnitude but opposite in sign to the soil water pressure.

mottled zone. A layer that is marked with spots or blotches of different color or shades of color.

order, soil. A category in the Canadian system of soil classification. All the soils of Canada have been divided into eight orders: Chernozemic, Solonetzic, Luvisolic, Podzolic, Brunisolic, Regosolic, Gleysolic, and Organic. All the soils within an order have one or more characteristics in common.

Organic. An order of soils that have developed dominantly from organic deposits. They contain 17% or more organic carbon.

oven dry soil. Soil that has been dried at 105°C until it has reached constant weight.

parent material. The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of a soil has developed by pedogenic processes.

parent rock. The rock from which the present materials of soils are formed.

particle density (grain density). The mass per unit volume of the soil particles. It is usually expressed in grams per cubic cm.

peat. Unconsolidated soil material consisting largely of undecomposed, or slightly decomposed, organic matter.

perched water table. A water table due to the "perching" of water or a relatively impermeable layer at some depth within the soil. The soil within or below the impermeable layer is not saturated with water.

permafrost. (a) Perennially frozen material underlying the solum. (b) A perennially frozen soil horizon.

physical properties of soils. The characteristics, processes, or reactions of a soil that are caused by physical forces, and are described by, or expressed in, physical terms or equations. Examples of physical properties are bulk density, water-holding capacity, hydraulic conductivity, porosity, and pore-size distribution.

Podzolic. An order of soils having podzolic B horizons (Bh, Bhf, or Bf) in which amorphous combinations of organic matter, aluminum, and usually iron are accumulated.

porosity. The volume percentage of the total bulk not occupied by solid particles.

Regosolic. An order of soils having no horizon development, or development of the A and B horizons insufficient to meet the requirements of the other orders.

relief. Elevations or inequalities of a land surface, considered collectively. Land having no unevenness or differences of elevation is called level; gentle relief is called undulating; strong relief, rolling; and very strong relief, hilly.

sand. (a) A soil particle between 0.05 and 2.0 mm in diameter. (b) Any one of five soil separates: very coarse, coarse, medium, fine, or very fine sand.

sandy. Containing a large amount of sand.

saturate. (a) To fill all the voids between soil particles with a liquid. (b) To fill to capacity, as the adsorption complex with a cation species; e.g., H-saturated.

silica-sesquioxide ratio. The molecules of SiO_2 per molecule of Al_2O_3 in clay minerals or soils.

silt. (a) A soil separate consisting of particles between 0.05 and 0.002 mm in equivalent diameter.

soil. (a) The unconsolidated material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. (b) The naturally occurring unconsolidated material on the surface of the earth that has been influenced by parent material, climate (including the effects of moisture and temperature), macro- and micro-organisms, and relief, all acting over a period of time to produce soil that may differ from the material from which it was derived in many physical, chemical, mineralogical, biological, and morphological properties.

soil-formation factors. The variable, usually intended natural agencies that are responsible for the formation of soil. The factors are parent rock, climate, organisms, relief, and time.

Solonetzic. An order of soils developed mainly under grass or grass-forest vegetation cover in semiarid to subhumid climates. The soils have a stained brownish solonetzic B (Bnt or Bn) horizon and a saline C horizon.

surface soil. The uppermost part of the soil that is ordinarily moved in tillage, or its equivalent in uncultivated soils. It ranges in depth from 2.5 to 7.5 cm (3 to 10 in) and is commonly designated as the plow-layer or the Ap horizon.

texture, soil. The relative proportions of the various soil separates in a soil as described by the classes of soil texture.

(a) sand - Soil material that contains 85% or more sand; the percentage of silt plus 1.5 times the percentage of clay does not exceed 15.

(b) loamy sand - Soil material that contains at the upper limit 85% to 90% sand, and the percentage of silt plus 1.5 times the percentage of clay is not less than 15; at the lower limit it contains not less than 70% to 85% sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

(c) sandy loam - Soil material that contains either 20% or less clay, with a percentage of silt plus twice the percentage of clay that exceeds 30, and 52% or more sand; or <7% clay, <50% silt, and between 43% and 52% sand.

(d) loam - Soil material that contains 7% to 27% clay, 28% to 50% silt, and <52% sand.

(e) silt loam - Soil material that contains ≥50% silt and 12% to 27% clay, or 50% to 80% silt and <12% clay.

(f) silt - Soil material that contains ≥80% silt and <12% clay.

(g) sandy clay loam - Soil material that contains 20% to 35% clay, <28% silt, and ≥45% sand.

(h) clay loam - Soil material that contains 27% to 40% clay and 20% to 45% sand.

(i) silty clay loam - Soil material that contains 27% to 40% clay and <20% sand.

(j) sandy clay - Soil material that contains ≥35% clay and ≥45% sand.

(k) silty clay - Soil material that contains ≥40% clay and ≥40% silt.

(l) clay - Soil material that contains ≥40% clay, <45% sand, and <40% silt.

(m) heavy clay - Soil material that contains >60% clay.

water table. Elevation at which the pressure in the water is zero with respect to the atmospheric pressure.

weathering. The physical and chemical disintegration, alteration, and decomposition of rocks and minerals at or near the earth's surface by atmospheric agents.

wilting point. The moisture content of a soil at which plants wilt and fail to recover their turgidity when placed in a dark, humid atmosphere. The wilting point is commonly estimated by measuring the 15-bar percentage of a soil.

zonal soil. Any one of the great groups of soils having well-developed soil characteristics that reflect the zonal influence of climate and living organisms, mainly vegetation, as actual factors of soil genesis.

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Institute for Defense Analyses
ATTN: Classified Library

Kaman Avidyne
ATTN: Library

Kaman Sciences Corp
ATTN: Library

Kaman Tempo
ATTN: DASIAC

Lockheed Missiles & Space Co, Inc
ATTN: Technical Information Center
ATTN: T. Geers

Lockheed Missiles & Space Co, Inc
ATTN: TIC-Library

McDonnell Douglas Corp
ATTN: R. Halprin

Merritt CASES, Inc
ATTN: J. Merritt
ATTN: Library

Pacific-Sierra Research Corp
ATTN: L. Schlessinger
ATTN: H. Brode

Pacifica Technology
ATTN: Tech Library

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Patel Enterprises, Inc
ATTN: M. Patel

Physics International Co
ATTN: L. Behrmann
ATTN: E. Moore
ATTN: F. Sauer
ATTN: Technical Library
ATTN: J. Thomsen

R & D Associates
ATTN: J. Carpenter
ATTN: W. Wright
ATTN: J. Lewis
ATTN: Technical Information Center
ATTN: R. Port
ATTN: P. Haas
4 cy ATTN: D. Oberste-Lehn

Science Applications, Inc
ATTN: Technical Library
ATTN: M. Mkcay
ATTN: H. Wilson

Science Applications, Inc
ATTN: D. Maxwell
ATTN: D. Bernstein

Science Applications, Inc
ATTN: W. Layson

Southwest Research Institute
ATTN: W. Baker
ATTN: A. Wenzel

SRI International
ATTN: G. Abrahamson

Systems, Science & Software, Inc
ATTN: D. Grine
ATTN: T. Riney
ATTN: T. Cherry
ATTN: R. LaFrenz
ATTN: Library
ATTN: K. Pyatt

Terra Tek, Inc
ATTN: S. Green
ATTN: Library

Tetra Tech, Inc
ATTN: L. Hwang

TRW Defense & Space Sys Group
ATTN: Technical Information Center
ATTN: D. Baer
ATTN: R. Plebuch
ATTN: I. Alber
2 cy ATTN: N. Lipner

TRW Defense & Space Sys Group
ATTN: E. Wong
ATTN: P. Dai

Universal Analytics, Inc
ATTN: E. Field

Energy Systems, Inc
ATTN: W. Ogle

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Weidlinger Assoc, Consulting Engrg
ATTN: J. Wright
ATTN: M. Baron

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Weidlinger Assoc, Consulting Engrg
ATTN: J. Isenberg

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