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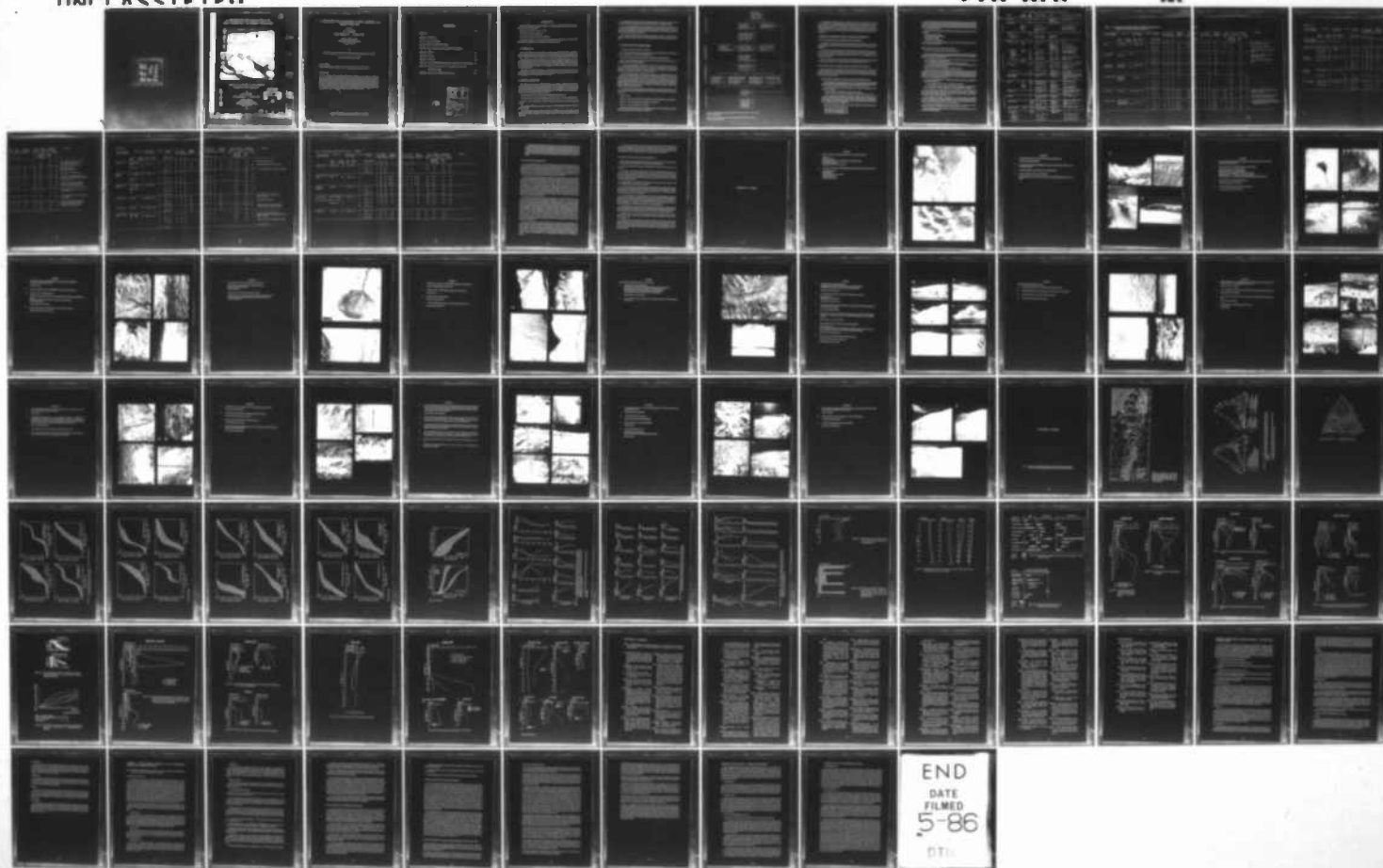
A PROCEDURE FOR EVALUATION OF DUST POTENTIAL IN DESERT
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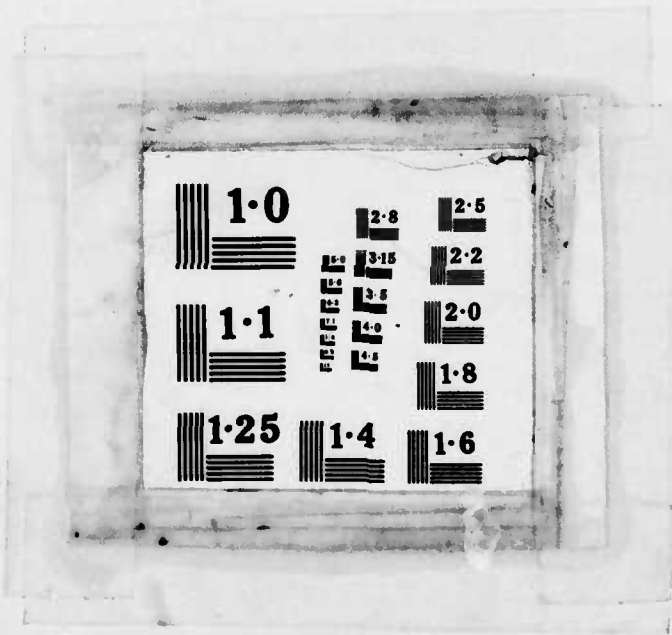
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A PROCEDURE FOR EVALUATION OF DUST POTENTIAL IN DESERT TERRAINS

AD-A166 491



BASED ON A STUDY IN THE DESERTS
OF ISRAEL AND THE SINAI

BY

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The US Army Research, Development and Standardisation Group, UK

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KEY WORDS

Dust Potential, Desert Landforms, Soils, Surficial Deposits, Silt, Clay, Sand.

ABSTRACT

The evaluation of dust potential in hot deserts is based on the association of well defined dust bearing soils and surficial deposits with specific landforms. These landforms are readily identified on airphotos (and in many cases on topographic maps and space imagery). The user may follow a sequence of operations, from the selection of a target area through the identification of relevant landforms and associated soils/surficial deposits, to the evaluation of the content, composition and distribution of dust in these media. The accompanying report is essential for the proper use of this procedure. *Keywords:*

Negev Desert.

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OBJECTIVES

The main objective of the present procedure is to present a method of characterization of dust at the surface, considering:

- (a) Amounts in different types of terrains.
- (b) Vertical and lateral distribution.
- (c) Particle size and mineralogical composition.

A secondary objective is to evaluate the general nature of ground cover and its possible effectiveness as a protective crust against the entrainment of dust.

1. INTRODUCTION

Dust is here defined as material composed of particles smaller than 0.063 mm in diameter. Dust in deserts (in both surficial deposits and the atmosphere) is usually composed of silt (0.063 - 0.002 mm) with minor amounts of clay (<0.002 mm) and fine sand (0.125 - 0.063 mm).

Dust in deserts is derived mainly from the following sources: (a) Products of in-situ rock weathering; (b) Alluvial and colluvial deposits; (c) Soils; (d) Eolian sediments - loess and sand; (e) Other deposits such as playa and lacustrine sediments. Dust is a "recycled" material; it is eroded or deflated from a site only to be deposited in another area where it may be trapped for any period of time.

The emission of dust is dependent on its availability at or near the surface, the type and effectiveness of the ground cover, cohesion of the potential dust layer, and the power of the driving agent (e.g. wind, man, machinery, explosives).

2. GENERAL PRINCIPLES

Since dust in most sites is an introduced material, its amounts, composition, and distribution should be related to the nature of the receptive surface, with respect to its texture, roughness, porosity, gradient, aspect, and vegetative cover. A soil emerges from a pre-existing parent material, its weathering products and the introduced dust. Well defined soil and surficial deposits are thus closely related to discrete landforms.

The following, then, are several related principles and generalizations:

- (a) Each type of soil or surficial deposit is associated with a narrow range of landforms.
- (b) The nature of landforms and soils (or deposits) is determined or highly affected by climate.
- (c) Certain landforms and soils are associated with well defined types of bedrock or parent material.
- (d) Landforms and soils change with time in a predictable manner. For example, more dust and or salts are added to the soil profile with time and their distribution is time-dependent.

(e) Certain types of ground cover are associated with given soil types. Such covers vary with parent material and climate, and they change with time in a predictable manner.

(f) One can subdivide desert soils and deposits into two general groups according to the parent material: (1) Gravelly soils and deposits. (2) Non-gravelly soils and deposits. The former contain a high proportion of gravel with variable amounts of dust and sand whereas the latter consists mainly of dust and/or sand.

(g) On certain landforms there is an orderly arrangement - sonation - of the soils and/or deposits, according to their association with landform components, location, gradient and aspect.

3. THE STRUCTURE OF THE PROCEDURE

The present procedure is based on two concepts:

(a) The characteristics of soils and deposits are closely associated with the landforms they are overlying or are derived from (see Appendix 4).

(b) Most landforms can be easily identified, using readily available airphotos.

Figure 1 provides a stepwise strategy for the evaluation of dust availability in deserts. The procedure consists of four general stages:

A. General Considerations: Definition and selection of target areas, assessment of their overall physiography and at the same time evaluation of dust tolerance for the intended operations in the selected target sites. These considerations and assessments are outside the scope of the present procedure and the accompanying report.

B. Selection/Identification of Relevant Landforms in the Target Areas. The use of airphotos of 1:10,000 - 1:30,000 is most desirable for identification/selection of the preferred landforms. Definite identification of landforms is essential for the assessment of the types of soils and deposits associated with them. Geologic, climatic and soil maps and data should be compiled while stage A (above) is carried out. The identification of the types of soils/deposits should be performed with extreme care; a thorough use of table 1, Appendix 1 (Plates) and Appendix 3 (Glossary) should be made.

C. Evaluation of Dust Availability, Distribution and Characterisation in the Various Types of Soils and Deposits. This is based on the data in table 2. Four topics are considered:

(1) Ground cover .

(2) Dust — amounts, size distribution, composition, vertical distribution and variability.

(3) Salts — amounts, composition, distribution and variability.

(4) Gravel — amounts and vertical distribution.

Special attention should be given to the high variability in the data presented in table 2. The large range of the data is explained in Appendix 5.

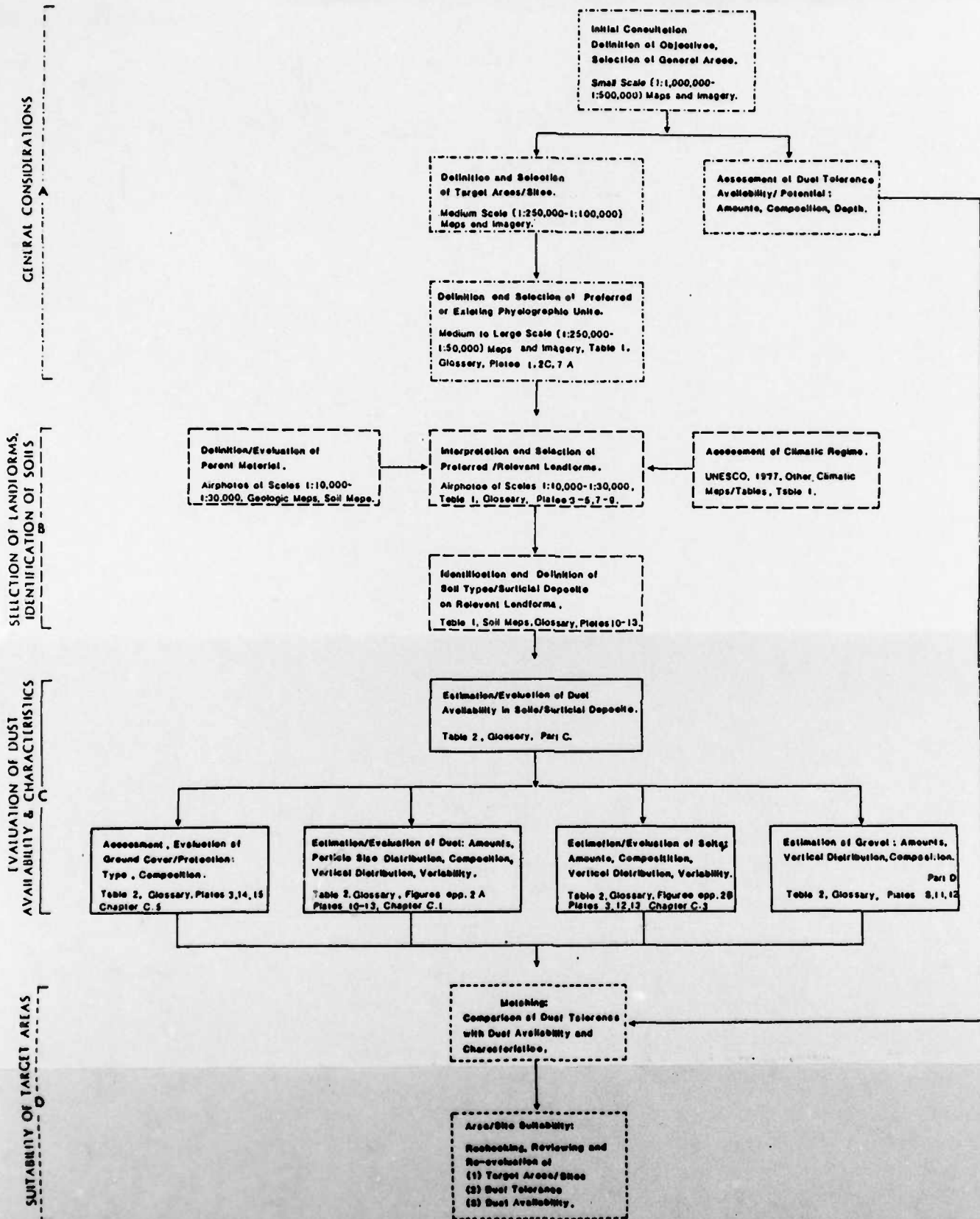


Figure 1. The structure of the procedure. Note the use of Parts C and D in the accompanying report.

(Reference: Unesco, 1977, Map of the world distribution of arid regions, with an explanatory note; Unesco, Paris, 54p.)

D. Suitability of Target Areas. A comparison of tolerance for dust (A, above) with dust availability and characteristics (C, above) may determine the suitability of a site for specific types of operation, or the utilisation of particular areas by certain instruments or vehicles. Suitability of a site for an operation may involve the ground cover, i.e., the number of runs that a vehicle or an aircraft may perform over a stretch of ground until its protective cover is destroyed.

4. DESERT LANDFORMS AND ASSOCIATES SOILS AND DEPOSITS

4.1 The Association Between Landforms, Soils and Deposits.

A subdivision of desert landscapes into landforms which are identifiable on areal photographs and large scale maps is the basis of table 1. The widespread terrain types in deserts are represented.

Twelve types of major landforms are presented in table 1. Further subdivision leads to a total of twenty landform types identifiable on airphotos. For the recognition and definition of the various types of landforms the reader is referred to Plates no. 1 - 9 in Appendix 1 and the Glossary in Appendix 3.

The last column of table 1 indicates the types of soils and deposits which are associated with the various landforms. The soils/deposits are described below, in section 4.2.

4.2 Evaluation of Dust Availability in Desert Soils and Surficial Deposits.

Table 2 summarises in quantitative terms the characteristics of the dust and the dust-related properties in desert soils and deposits. The data base for this summary is derived from the soils and deposits of the Negev, Sinai, Judean Desert and the Jordan Valley (see Appendix G.3 in the accompanying report).

Notes on Table 1: Physiographic Units, Landforms and Associated Soils/Surficial Deposits.

The table relates soil types and surficial deposits to the various landscape features (physiographic units or landforms) that are widespread in deserts. Table 1 is followed by table 2 which characterizes soils by their dust attributes and some other properties, such as gravel and salt content.

The subdivision of landscape selected here enables the user to separate landscape features according to two categories:

1. Landforms that have a clear signature on regularly used visual aids.
2. Landforms that carry soils that may be easily identified and are different from each other.

All of the widespread desert landforms are included. The general order of the landforms in the table reflects the abundance of dust in the soil and to a certain degree takes into account the frequency of occurrence of the landforms in desert terrains. Since we could not closely examine Mid-Eastern soil only in the Negev and the Sinai, the data reflect desert terrains in these regions; they are, however, very similar to other desert terrains in the Middle East.

Many technical terms are used in table 1. Their meaning is presented in the Glossary (Appendix 3).

Relief types are subdivided into three groups:

1. Mountains: relief > 200m; gradients > 20°.
2. Hills: relief of 20-200m; gradients > 15°.
3. Plains: relief < 20m; gradients usually < 10°.

Source and parent materials of different hardness, weatherability and erodibility may determine soil nature. Hard, durable rocks, such as dolomite, flint, syenite and diorite, usually weather into gravel, which harbours dust and salts from external sources (windborne and washed-in by water). Soft, friable rocks such as shales, chalks sandstones and mudstones weather down to sand and finer fractions, mixed with external dust and salts.

The climate in hot arid environments is here subdivided into four regimes, according to mean annual precipitation:

1. Semi-arid - 250-400 mm/year;
2. Moderately arid - 150-250 mm/year;
3. Arid - 80-150 mm/year;
4. Extremely arid - < 80 mm/year.

The types of soils and surficial deposits on a given landform are listed in decreasing order of frequency on the particular landform.

Notes on Table 2: Soils Type and Surficial Deposits in Deserts

(note numbers are marked at the head of the appropriate columns)

(1) There is no single principle which can guide an objective grading of desert soils according to their dust content, composition and distribution. Therefore, the types of soils and surficial deposits are organized according to the following guidelines:

- (a) The abundance of dust in the soil profile, maximal in loessial and Takyr soils, and minimal in active sand dunes and coarse gravelly alluvium.
- (b) The association of the soil (or deposit) with a particular type of landform.
- (c) The age of the soil, within a given soil type. In most soils there is an increase of fine fractions (including precipitated salts) with time.

A detailed description of the main soil types is presented in Appendix 4.

(2) Most soils in deserts develop a surficial layer or crust rather rapidly. Such a cover is different in composition and structure from the underlying layers or horizons; often the surficial layer is more cohesive and may determine the degree of potential of dust emission. Different ground covers are presented in table 2, according to their texture, composition and the percentage of areal coverage. The types of cover are (see details in Appendix 6):

- (a) Loess crust (dense and thin - 1-3 mm thick) on loessial soils, Takyr soils and between large particles in gravelly soils.
- (b) Salt and gypsum crusts on Solonchak soils in playas and sabkhas.
- (c) Desert pavement, usually composed of flat lying gravel developed on old gravelly deposits, with >40% gravel cover and an interstitial loess crust. See Appendix 3 for elaboration.

(3) The thickness of the soil profiles and horizons is most variable for many soils. The range and average is not always based on a large number of observations or measurements. The data include soils of different ages, degrees of development, and aspects. Hence the range of data should be considered as well as the averages (see Appendix 5).

(4) The designation of soil horizons is generalized with A, B, and C without further subdivision. This is so for the comparison of the general characteristics of the horizons and incorporation of data from sources additional to those collected in the present study. For a detailed description and designation of sub-horizons see Appendix G.2 in the accompanying report.

(5) The textural subdivision employed here is as follows: (a) Sand - 2.0-0.063 mm. (b) Silt - 0.063-0.002 mm. (c) Clay - <0.002mm. Dust is defined as silt and clay - <0.063 mm.

(6) The data represent estimates in the field. <2 mm includes fine earth, i.e. sand, silt and clay. The remainder is undifferentiated gravel.

Table 1: Physiographic Units, Landforms and Associated Soils/Surficial Deposits.

Landform	Landform Component	Relief Type	Source/Parent Material	Climate	Soil Type; Type of Surficial Deposit		
Plain, Piedmont	Loess Plain		Loess	Semi-arid to Moderately Arid	Loess, Loessial Soil		
	Playa, Sabkha	Plain		Arid to Extremely Arid	Takyr Soil, Solonchak Soil		
		Center Transition Zone Margin	Fine Alluvium	Sandy to Fine Alluvium Gravelly to Sandy Alluvium	Solonchak Soil, Takyr Soil Reg Soil, Solonchak Soil		
Sand Dune		Hill, Plain	Sand				
	a. Stabilized Dune b. Active Dune		Semi Arid to Arid Arid to Extremely Arid	Sandy Regosol Eolian Sand Arid			
Plain, Piedmont, Plateau	Terrace	Terrace Tread	Plain	Coarse Alluvium	Arid to Extremely Arid	Reg Soil	
				Loess	Semi-arid to Moderately Arid	Loess, Loessial Soil	
				Sand	Semi-arid to Extremely Arid	Alluvial Sand, Sandy Regosol	
	b. Alluvial Fan Terrace	Terrace Tread	Plain	Coarse Alluvium	Arid to Extremely Arid	Reg Soil, Gravelly Regosol (on sieve deposits)	
			Hill, Plain	Coarse Colluvium/ Alluvium	Arid to Extremely Arid	Reg Soil, Gravelly Regosol	
	c. Transition Talus-Alluvial Terrace		Hill, Plain	Coarse Alluvium	Arid to Extremely Arid	Coarse Desert Alluvium, Incipient Reg Soil	
	d. Ballena		Hill, Plain	Coarse Alluvium	Arid to Extremely Arid	Reg Soil	
	e. Rockcut Terrace	Terrace Tread	Plain	Hard/Soft Bedrock	Arid to Extremely Arid	Hammada, Lithosol	
	Fan	a. Alluvial Fan	Plain	Coarse Alluvium	Arid to Extremely Arid	Coarse Desert Alluvium, Incipient Reg Soil	
				Coarse and/or Fine Alluvium	Arid to Extremely Arid	e.g. Brown Alluvial Soil, Alluvial Gley	
b. Debris Flow Fan		Plain	Debris Flow Deposits	Moderately Arid to Extremely Arid	Debris Flow Deposit, Sieve Deposit, Gravelly Regosol		
Active Channel and/or Floodplain		Plain	Coarse and/or Fine Alluvium	Semi-arid to Extremely Arid	Gravel, Sand, Silt, Clay, in Varying Proportions: Coarse Desert Alluvium, Alluvial Sand, Loess, Incipient Reg Soil		
Hillslope, Escarpment	Plateau	Crest	Plain, Hill	Hard, Brittle Bedrock	Semi-arid to Extremely Arid	Hammada Soil, Lithosol	
		Flat Divide Saddle	Plain	Hard, Brittle Bedrock	Semi-arid to Extremely Arid	Hammada Soil, Lithosol	
			Hill	Hard Brittle or Soft, Erodible Rocks	Semi-arid to Extremely Arid	Lithosol, Loessial Serozem, Serozem, Hammada Soil	
	Undulating Hills		Hill	Soft, Erodible Rocks, Loess, Sand	Semi-arid to Extremely Arid	Loessial Soil, Dune Sand, Alluvial Sand, Sandy Regosol, Lithosol, Serozem Soil	
	Badlands		Hill	Soft Erodible Bedrock, (loess, shale, marl, chalk)	Semi-arid to Extremely Arid	Lithosol, Regosol, Loess	
	Rocky Hillslope		Mountain, Hill	Hard, Brittle Bedrock	Semi-arid to Extremely Arid	Lithosol (not continuous, often in patches)	
			Mountain, Hill	Soft, Erodible, Friable Bedrock	Semi-arid to Extremely Arid	Lithosol, Regosol, (often in patches)	
	Colluvial Hillslope	Footslope	Mountain, Hill	Hard, Brittle and/or Soft Erodible Rocks	Semi-arid to Extremely Arid	Loessial Serozem, Lithosol	
	Talus Hillslope		Mountain, Hill			Moderately Arid to Extremely Arid	
				a. Debris Flow Talus	Debris Flow Deposits	Gravelly Regosol, Reg Soil	
b. Sieve Deposit Talus				Sieve Deposits	Gravelly Regosol, Reg Soil		
c. Rockfall Talus				Rockfall Deposits	Gravelly Regosol, Reg Soil		

TABLE 2 SOIL TYPES AND SURFICIAL DEPOSITS IN DESERTS: GROUND COVER, PROFILE CHARACTERISTICS, DUST AND SALTS

Soil Type; Type of Surficial Deposit	Ground Cover ²		Thickness of ³ Soil / Deposit		Horizon ⁴	Thickness of Horison		Silt + Clay, % ⁵ of the < 2mm Fraction(average)			Average ⁶ Estimated < 2mm, %	Soil (aver Clay %
	Type of Cover	Average Cover, %	range cm	average cm		range cm	average cm	min	max	ave		
Loess	loess crust	100	43-200	131	A	5-35	20	16	19	51	100	37.2
				B	96-132	114	36	92	55	100	44.1	
				C	96-120	108	17	79	52	100	-	
Brown Loessial Soil	sandy loam	100			A	7-41	24	54	70	64	100	-
					B	73-104	88	61	72	68	100	-
					C	103-135	119	59	64	61	100	-
Light Brown Loessial Soil	silty clay loam crust	100	165-210	157	A	0-28	14	30	80	46	100	-
				B	54-80	67	20	87	51	100	-	
				C	115-157	136	4	92	38	100	-	
Loessial Serozems	loess with some rock fragments		82-191	87	A	1-17	9	39	81	65	-	-
				B	61-87	74	50	91	76	-	-	
				C	92-116	104	74	81	77	-	-	
				Bb	121-166	143	71	78	75	-	-	
Takyr Soil	loess crust	100	40-180	89	A	1-14	7	55	100	82	95-100	41.2
				B	13-22	18	64	100	79	95-100	58.2	
				C	37-65	50	64	100	84	95-100	33.5	
Solonchack Soil	salt crust or saline loessial /sandy crust	100	30-140	102	A	3-12	8	21	89	61	90-100	3.6
				B	69-102	86	89	91	90	50-100	-	
				C	15-46	30	15	36	28	50-100	3.4	

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Page	Silt + Clay, % ⁵ of the < 2mm Fraction(average)			Average ⁶ Estimated < 2mm, %	Soil Binding Components ⁷ (average in the < 2mm fraction)				Comments
	min	max	ave		Clay %	Electrical conductiv- ity mho/cm	Salts	Approx- imate %	
0	16	19	51	100	37.2	0.5	0.03	-	Parent material - loess.
1	36	92	55	100	44.1	1.4	0.09	-	Land is usually cultivated.
3	17	79	52	100	-	4.2	0.26	-	Variable friability of surficial crust.
4	54	70	64	100	-	0.9	0.06	-	The natural vegetation is of grass steppe type.
8	61	72	68	100	-	0.7	0.04	-	The soil contains pedogenetic CaCO ₃
9	59	64	61	100	-	0.2	0.01	-	
4	30	80	46	100	-	0.6	0.04	-	
7	20	87	51	100	-	0.5	0.03	-	
6	4	92	38	100	-	0.8	0.05	-	
9	39	81	65	-	-	2.6	0.16	0.5	
4	50	91	76	-	-	15.6	0.98	2.9	
4	74	81	77	-	-	28.0	1.75	6.8	
3	71	78	75	-	-	21.6	1.35	6.2	
7	55	100	82	95-100	41.2	9.6	0.6	0.5	High soil moisture during at least part of the year.
8	64	100	79	95-100	58.2	34.4	2.15	3.2	Note zonation according to particle size, salinity and vegetation.
0	64	100	84	95-100	33.5	31.7	1.98	4.0	
8	21	89	61	90-100	3.6	24.8	1.55	4.5	A relatively high sand contents in coastal belts and in terrains adjacent to sandstone exposures
8	89	91	90	50-100	-	4.1	0.26	-	
0	15	36	28	50-100	3.4	60.4	3.78	8.0	

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TABLE 2 (cont.)

Soil Type:Type of Surficial Deposit	Ground Cover Type of Cover	Average Cover, %	Thickness of Soil / Deposit		Horizon	Thickness of Horizon		Silt + Clay, % of the < 2mm Fraction(average) < 2mm, %			Average Estimated < 2mm, %	Cl
			range cm	average cm		range cm	average cm	min	max	ave		

Surficial Sediment												
Coarse Alluvium	Coarse gravel	100	10-100	57	A	-	-	-	-	12	-	tr
					C	-	-	4	9	6	-	tr

Reg Soil, Holocene	desert pavement	48	35-50 (130*)	40	A	2-5	3.5	15	88	60	20	1
	fluvial gravel	42			B	3-9	5.5	14	88	60	25	1
	loess crust	10			C	14-40	27.1	1	75	33	20	

Reg Soil, Pleistocene	desert pavement	84	60-135	53	A	1-6	4	14	84	49	40	
	loess crust	16			B	10-22	16	12	86	48	40	12
					C	30-53	42	3	84	33	40	10
					Bb	20-34	27	18	86	55	-	15

Reg Soil, Tertiary	desert pavement	97	150	150								
	loess crust	3			B**	9-12	10	58	88	78	60	22
					Bb	100	100					

Gravelly Regosol	loose gravel	93	30-150	56	A	8-15	8	3	99	47	30	12
	sand and loess	7			B	2-9	8	5	62	20	40	3
					C	33-38	35	7	75	39	10	5

Silt + Clay, % of the < 2mm Fraction(average) < 2mm, %			Average Estimated < 2mm, %	Soil Binding Components (average in the < 2mm fraction)			Comments	
min	max	ave		Clay %	Electrical conductiv- ity mho/cm	Salts Approx- imate %	Gypsum %	
-	-	12	-	tr.	10.9	0.68	0	Poor cohesion. Low clay content. Good water penetration.
4	9	6	-	tr.	21.6	1.35	0.1	Scattered bushes and trees.
15	88	60	20	11.2	8.0	0.5	0.6	Notes on Reg Soils: Highly gravelly soils.
14	88	60	25	14.2	14.2	0.89	2.6	Mostly devoid of vegetation.
1	75	33	20	4.8	12.0	0.75	2.1	
14	84	49	40	9.8	10.3	0.64	0.9	A horizon is here defined as the fine top soil underneath and between surficial cover.
12	86	48	40	12.7	22.7	1.42	3.5	
3	84	33	40	10.4	20.7	1.29	6.8	The soil is moist only during and after infrequent rainfall events, usually to depth < 20 cm.
18	86	55	-	15.6	16.3	1.02	39.0	*Holocene Reg soils 50-130 cm thick are rather rare.
58	88	78	60	22.9	17.8	1.11	10.9	**A single profile; only B horizons were sampled.
3	99	47	30	11.1	30.7	1.92	5.6	The gravelly Regosols presented here are developed on sieve deposits, on talus slopes.
5	62	20	40	3.5	8.9	0.56	1.2	
7	75	39	10	5.4	10.2	0.64	3.5	

TABLE 2 (cont.)

Soil Type; Type of Surficial Deposit	Ground Cover		Thickness of Soil / Deposit		Horizon	Thickness of Horizon		Silt + Clay, % of the < 2mm Fraction (average) < 2mm, %			Average Estimated < 2mm, %
	Type of Cover	Average Cover, %	range cm	average cm		range cm	average cm	min	max	ave	
Hamada Soil	coarse angular gravel	88	30-100	50	A	1-6	4	81	92	70	35
	loess crust	14			B	8-21	15	29	83	64	55
					C	32-50	41	16	64	40	35
Lithosol Serozen	rock fragments	50	55-100	40	A	0-14	7	37	79	61	-
	loess & fine sand	50			B	16-39	27	58	84	71	-
					C	24-40	32	60	82	71	-
Stony Alluvial Serozen	rock fragments	60	40-240	142	A	2-18	10	39	85	64	-
	loess & fine sand	40			B	52-78	65	27	63	78	-
					C	115-142	129	51	95	70	-
					Bb	118-155	136	76	89	83	-
Alluvial Sand	fine sand	100	106-300	188	A	0-35	17	16	29	22	100
					B	44-90	67	8	29	18	100
					C	142-188	165	2	11	5	100
Sandy Regosol	fine sand	100	40-250	193	A	0-49	20	-	-	12	100
					C	142-188	165	9	16	13	100
Brown Alluvial Soil	silty clay loam Crust	100	200-250	121	A	2-8	10	29	71	46	-
					B	85-120	102	65	82	74	-
					C	87-121	104	10	86	42	-
					Bb	113-150	131	-	-	-	-

Silt + Clay, % of the < 2mm Fraction(average) < 2mm. %			Average Estimated < 2mm. %	Soil Binding (average in the < 2mm fraction)		Components		Comments
min	max	ave	Clay %	Salts Electrical conductiv- ity mmho/cm	Approx- imate %	Gypsum %		
61	92	70	35	12.7	4.1	0.28	0.1	Highly gravelly soils.
29	83	64	55	18.5	22.2	1.39	13.1	Sparse vegetation, grass, bushes.
18	64	40	35	18.5	7.0	0.44	4.8	frequently appear in patches, pockets.
37	79	61	-	-	4.4	0.28	-	
58	84	71	-	-	6.0	0.38	0.6	
60	82	71	-	-	4.6	0.29	5.4	
39	85	64	-	-	16.5	1.03	0.1	
27	63	78	-	-	10.8	0.68	12.1	
51	95	70	-	-	25.4	1.59	7.2	
78	89	83	-	-	5.9	0.37	-	
16	29	22	100	-	0.4	0.03	0	Poor cohesion of the soil and the soil crust.
8	29	18	100	-	0.3	0.02	0	Good water percolation.
2	11	5	100	-	0.3	0.02	0	
-	-	12	100	-	0.3	0.02	0	Higher content of fines and better cohesion where vegetated (bushes).
9	18	13	100	-	0.2	0.01	0	
29	71	46	-	-	13.9	0.87	0.2	The soil is highly variable in gravel content, salinity and vegetation (grass, bushes).
65	82	74	-	-	28.0	1.75	0.1	
10	86	42	-	-	11.2	0.70	-	The soil may contain pedogenetic CaCO ₃
-	-	-	-	-	-	-	-	One case of Bb.

2

TABLE 3 Soil Types and Surficial Deposits -- a Summary

Soil Type;Type of Surficial Deposit	Ground Cover	Average Cover,%	Thickness of Soil / Deposit		Horizon	Thickness of Horison		Silt + Clay, % of the < 2mm Fraction(average) < 2mm, %			Average Estimated < 2mm, %
			Type of Cover	range cm		average cm	range cm	average cm	min	max	
Loessial Soil	loess crust	100	43-210	120	A	3-29	16	16	91	57	-
					B	64-95	79	20	92	66	-
					C	102-133	116	4	92	53	-
Takyf & Solonchak Soils	loess & salt crust	100	30-180	95	A	-	-	21	100	70	95-100
					B	-	-	64	100	85	95-100
					C	-	-	16	100	74	95-100
Surficial Sediments	Variable	-	10-240	65	A	3-14	8	3	98	45	30
					B	3-13	8	5	62	20	30
					C	32-57	44	4	75	33	10
Gravelly Soils	desert pavement	65	30-150	54	A	1-6	4	7	92	55	35
Reg Soils,Soils,Lithosols	gravel		25		B	10-21	15	2	68	53	40
	loess crust	10			C	27-52	39	1	64	33	35
					Bb	83-103	93	-	-	-	-
Sandy Soils	fine sand	100	40-300	190	A	0-36	18	12	29	19	100
					B	45-91	68	8	29	18	100
					C	143-190	166	2	16	7	100

Silt + Clay, % of the < 2mm Fraction(average)			Average Estimated < 2mm, %	Soil Binding Components (average in the < 2mm fraction)			Comments
min	max	ave		Clay %	Salts Electrical conductiv- ity mmho/cm	Approx- imate %	Gypsum %
16	91	57	-	37.2	1.2	0.08	0.5
20	92	66	-	44.1	8.2	0.51	2.9
4	92	53	-	-	5.7	0.36	6.8
21	100	70	95-100	22.4	18.4	1.15	2.2
64	100	85	95-100	58.2	19.3	1.21	3.1
16	100	74	95-100	23.4	39.7	2.48	5.1
3	98	45	30	11.1	29.7	1.88	5.4
5	62	20	30	3.5	8.9	0.56	1.2
4	75	33	10	5.4	12.2	0.76	2.8
7	92	55	35	10.5	9.1	0.57	0.7
2	88	53	40	13.8	21.7	1.36	4.0
1	84	33	35	7.4	17.4	1.09	5.3
-	-	-	-	-	-	-	-
12	29	19	100	tr.	0.4	0.03	-
8	29	18	100	tr.	0.3	0.02	-
2	16	7	100	tr.	0.3	0.02	-

(7) Several soil components affect soil consistency. Clay and salts (chlorides, gypsum, carbonate) are prominent among these. Chlorides and gypsum are the characteristic precipitates in the soils here considered. In some other deserts, such as the Mojave, carbonate predominates. Electrical conductivity represents the content of soluble salts, mostly NaCl; 16 mmho/cm equals approximately 1% of soluble salts. The data presented here are in percents of the fine earth fractions of the soil or deposit. The quantitative effects of each of the three components on their observed combinations are not yet established.

4.3 Some Practical Considerations.

(a) Particulate materials in soils and other deposits are universally subdivided into three size groups: (1) Dust (or fines), i.e. silt and clay; (2) Sand; (3) Gravel. Fine earth is treated here extensively since it is composed of dust and sand, the finer fractions of which may be raised as airborne dust for short periods and distances. Gravel is used only as a very general term. The reader is referred to part D in the accompanying report for background and possible implications of gravelly/non-gravelly materials in the soils and other deposits.

(b) Dust in soils and other deposits is composed of two main groups of particles: (1) Silicate and carbonate mineral particles which were incorporated in the soil in their original solid state; (2) materials that were incorporated in the soil or deposit by precipitation from introduced water — rain and groundwater. Such materials appear as dust particles (e.g., crystals and aggregates) in early stages of soil development. They become denser and harder with time. Their composition is mainly CaCO_3 , gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and chlorides (mainly NaCl). CaCO_3 is a major constituent of the original mineral particles in dust of many deserts, and the separation of secondary carbonate is not practical. The separation of gypsum and salts is universally carried out by dissolution so that the quantitative concentration as various dust fractions of recognized size is not known.

(c) Dust sized particles in the soil and other deposits are composed of both discrete crystalline particles and particulate aggregates. Aggregates are grown of primary particles bound to form secondary units. Clay and salts are binding agents. The resulting aggregates may be of various sizes and have different degrees of strength and cohesion upon release by dust producing agents. At present, there is no method which enables us to predict the size, consistency, and persistence of such aggregates in the different soils and under possible applied stress. However, there are several components that may be evaluated, as they cause binding of discrete particles. These include clay, gypsum, carbonate and soluble salts. Whereas clays are not a major component in many desert soils and deposits, various salts are found in significant quantities. However, in order to deliver an objective background for dust evaluation, the fine earth materials are dispersed into their component fractions in the laboratory, e.g. sand, silt, clay, gypsum, chloride salts, etc.

(d) All the soils, with the possible exception of the very recent ones, are polygenetic, having developed under effective changes in climatic regimes. This implies changes in rainfall, effective infiltration, dust penetration, and precipitation of salts in various horizons and to differential depths. The climatic progression during the Quaternary for most deserts is not sufficiently known. Even for the late Quaternary, which is best understood, the effectiveness of climatic changes and the identification of such fluctuation in soils may be only roughly generalised.

(e) The age of most aridic soils is not known, and the age of others is only broadly estimated, with designations such as Holocene, late Pleistocene, Pleistocene and Tertiary. The degree of soil development (marked especially by silt, clay and salt content and distribution) is time dependent; it can be evaluated only in a very general way (see Appendix 5).

4.4 Summary of Some Points of Further Emphasis.

While using the present procedure one has to bear in mind several trends which assist in evaluating the amounts, distribution and composition of dust in deserts:

(1) Old surfaces usually contain higher amounts of dust and salts than young ones in the same area.

(2) Sorting of sediments downflow leads to fining of deposits both downstream and downwind. Areas covered by fluvial deposits may contain large amounts of dust sized materials if they are located far downstream from the sources of the detritus, i.e. the center of the playas. Areas far away from sources of sand will contain large amounts of fine sized dust and almost no sand (including fine sand).

(3) Areas which are located downwind from sources of dust may contain more dust in their soil and deposit than in areas upstream or upwind.

(4) Dust is trapped in large quantities in areas where vegetation, especially grass, is dense. Hence, the less arid terrains are more favourable to dust accretion and residence. This guideline applies also to hillslopes which are exposed away from the sun, i.e. hillslopes having a northern aspect in the northern hemisphere.

(5) In most Mid-Eastern aridic soils there is a transition from precipitated carbonate in the semi-arid and modestly arid environments to gypsum and chloridic salts precipitated in the soils of the arid and the extremely arid environments. Gypsum and salts are not the dominant precipitates in all deserts. For example, the Mojave and the Sonoran Deserts in southeastern California and Western Arizona calcic soils are widespread.

(6) Old gravelly soils usually have a gravel-free B horizon several tens of cm thick, underlying a gravelly desert pavement. Such soils are rapidly denuded of their pavement and B horizon upon gullying and an indurated calcic or gypsumic crust may be exposed at the surface.

(7) Information on the type and condition of ground cover may require airphotos of the scales 1:2,500 - 1:10,000. Areas should be studied with this kind of imagery when landing of aircraft is planned.

(8) Hillslopes of gentle declivity, $<20^\circ$, may have developed some kind of soil; including relatively large amounts of dust. Still, these amounts are usually far less than those characteristic of soils on the gently sloping surfaces on the upper part of the same landforms. Such is the case of Reg soils on alluvial surfaces richer in dust than the gravelly Regosols on the riser slopes at their foot.

APPENDIX 1 PLATES

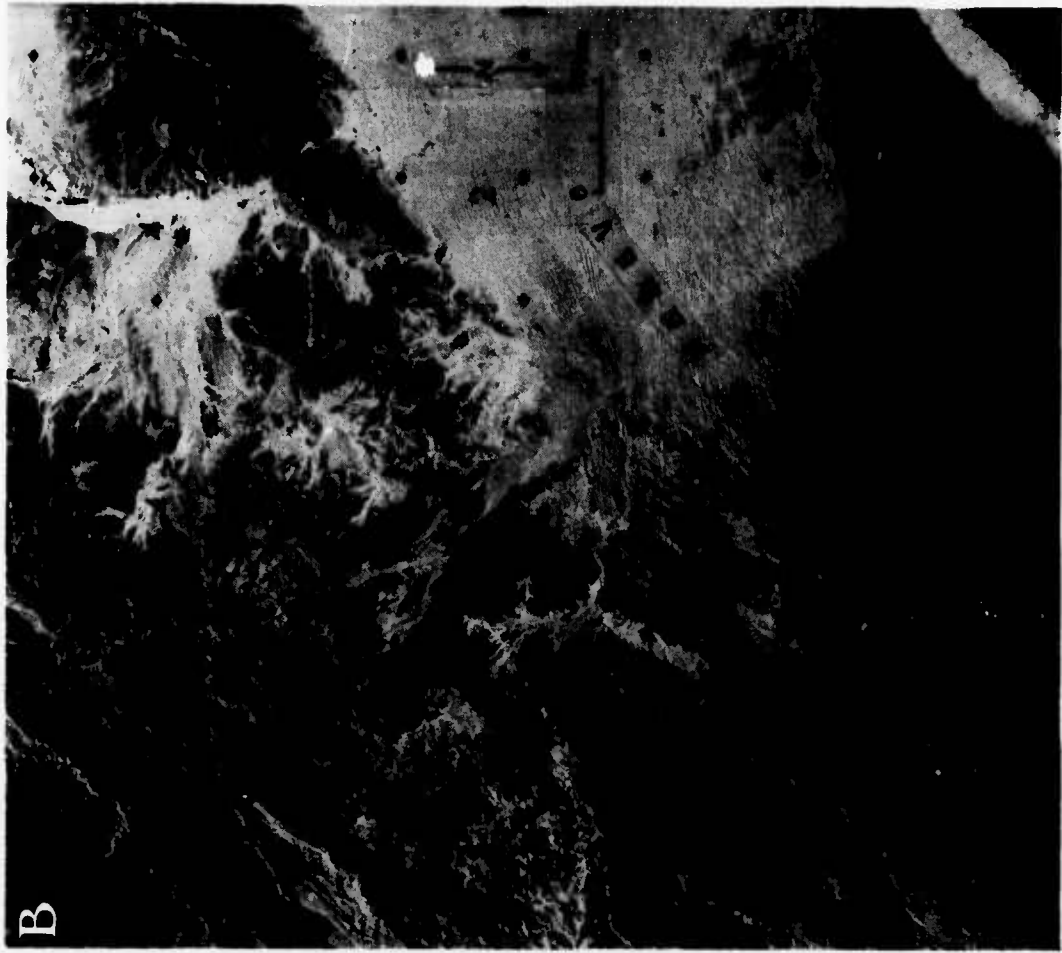
PLATE 1

A Typical landforms of dissected limestone terrains (northern Negev):

- (1) Crest.
- (2) Rocky hillslope.
- (3) Interchanging rocky scarplets with loess covered benches.
- (4) Colluvial footslope.
- (5) Dissected colluvial - alluvial fill.

B A portion of the Negev on a satellite imagery. Note several broad landscape types:

- (1) Loessial terrains.
- (2) Dune fields.
- (3) Dissected limestone terrains.
- (4) Alluvial plains.
- (5) Limestone plateaus.



B



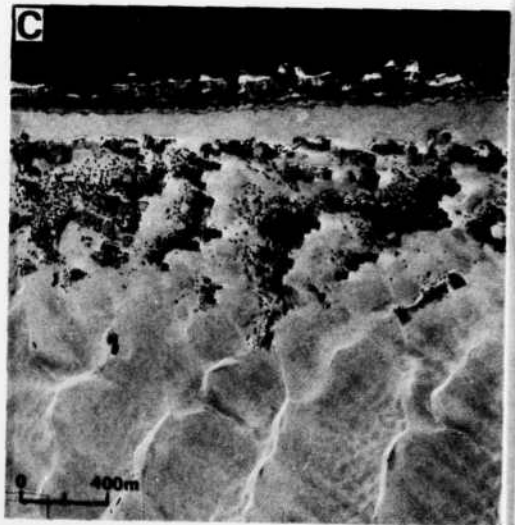
PLATE 2

- A** A stabilised sand dune (1) overlain by an active climbing dune (2).
Mt. Qeren, northwestern Negv.
- B** An active dune with ripples climbing over the ruins of Byzantine Rehovot in the northwestern Negv.
- C** Longitudinal dunes along the coast of northeastern Sinai.
- D** Loess overlying chalk in the northern Negv.
Note the thicker loess mantle on the north facing hillslope (righthand side of the photo).

A



C



B



D



PLATE 8

- A** The playa of Qa En-Naqb, southern Negev, surrounded by alluvial fans. Takyr soils characterize the playa surface.
- B** A playa bordered by alluvial fans (southern Arava Valley).
(1) Old alluvial fans mantled by Reg Soils.
(2) Active alluvial fan — sand and gravel.
(3) Outer playa sone (vegetated) — silty sand and sand.
(4) Transition sone — sandy silt, saline and gypsiferous.
(5) Inner playa sone — sandy and silty clay, highly saline and gypsiferous.
- C** Soft, puffy and wet silty-clayey playa surface.
Avrona playa, southern Arava Valley.
- D** Soft, puffy, highly saline and sterile inner playa sone.
Avrona playa, southern Arava Valley.

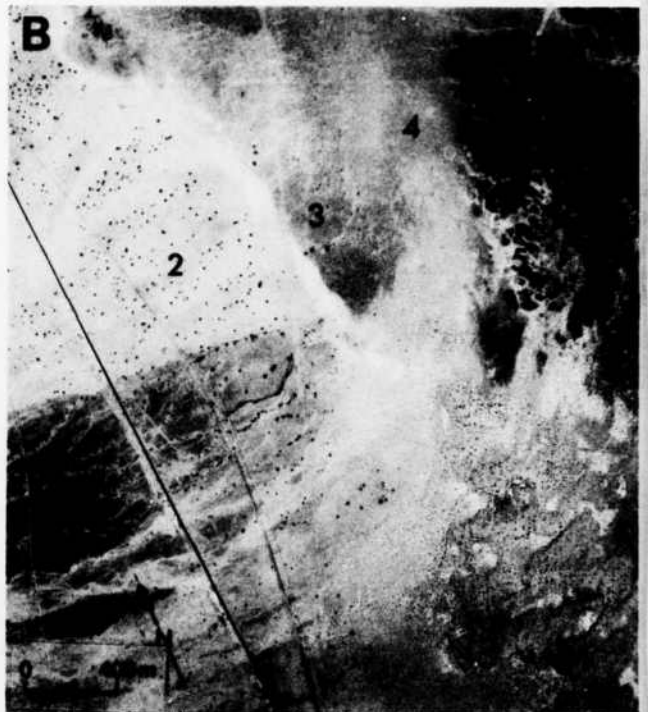


PLATE 4

- A** (1) Alluvial surfaces of different Quaternary ages mantled by Reg soils.
(2) The extensive plays of Al Jafr.
Southern Jordan.
- B** Holocene alluvial surfaces of Nahal Hever, draining into the Dead Sea.
- C** Alluvial surfaces of different ages:
(1) Pleistocene surfaces with a well developed desert pavement over a smooth surface.
(2) Holocene surfaces with a gravel bar and swale morphology.
(3) Active floodplain.
Timna Valley, southern Negev.
- D** Dissected alluvial fans with rounded and narrow ridges - ballenas.
Nahal Roded, southern Arava Valley.

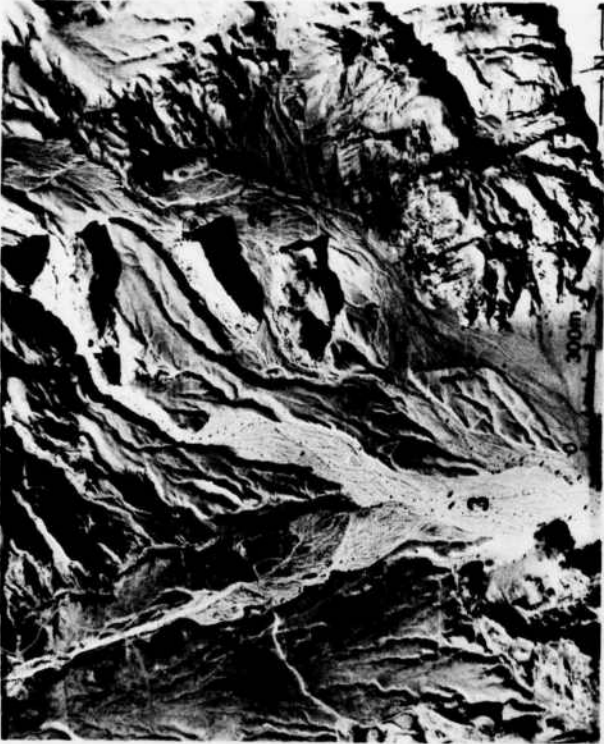


PLATE 5 .

A The complex alluvial fan of Wadi Wattir, eastern Sinai:

- (1) Alluvial fan composed primarily of gravel and sand.
- (2) A belt of active sand dunes.
- (3) Coastal sabkha.

B Surficial patterns of alluvial fans (Eastern Sinai):

- (1) Pleistocene surfaces, smooth with a well developed desert pavement.
- (2) Holocene surfaces with well preserved gravel bars and swales.
- (3) Active floodplains.

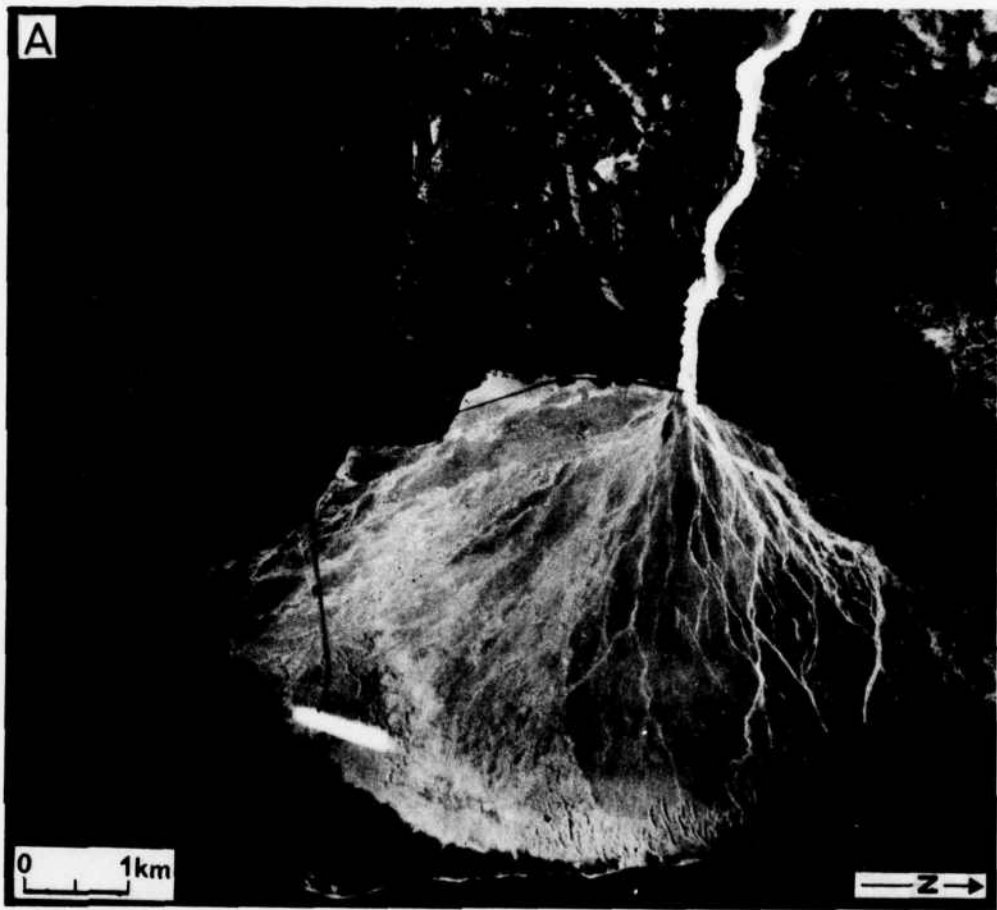


PLATE 8

- A** Debris flow fan surfaces of Holocene age, composed of sieve deposits.
South of Wadi Mukeibila, eastern Sinai.
- B** A debris flow fan of Holocene age, composed of sieve deposits.
Eastern Sinai.
- C** Recently deposited sieve deposits.
Wadi Naseb, eastern Sinai.
- D** A recently deposited debris flow with sieve deposits at the surface.
Wadi Naseb, eastern Sinai.



A



B



C



D

PLATE 7

Some landforms associated with major escarpments:

- A**
- (1) A plateau with Hammada soils.
 - (2) Talus relicts, composed of debris flow deposits mantled by Reg soils.
 - (3) Transition between talus and bajada, mantled by Reg soils.
 - (4) Middle Pleistocene alluvial fan terraces with Reg soils.
 - (5) A late Quaternary alluvial fan terrace with Reg soil.

Makhtesh Ramon, central Negev.

- B**
- An active talus slope. Note recently active debris flows. South of Wadi Mukeibila, eastern Sinai.

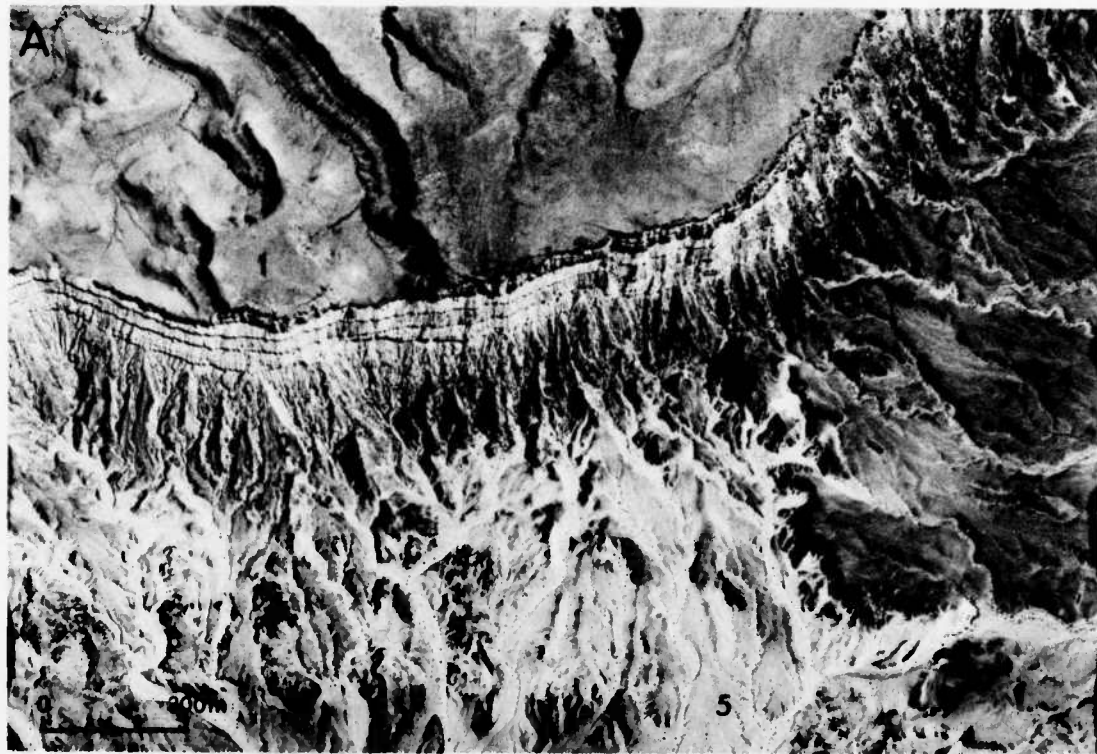


PLATE 8

- A** (1) Hillcrest flat with Hammada soil.
(2) Limestone benches with loessial Serossem soils and Lithosols.
(3) Foothlope colluvium with calcic and gypsic loessial soils.
Nitsana area, western Negev.
- B** An undulating high plateau. The soils are highly clayey and calcic.
(1) Hammada soil.
(2) Clayey, calcic loessial soil.
Mt. Katerina, southern Sinai.
- C** Talus slopes composed of rockfall debris and sieve deposits. The bedrock lithology is rhyolitic quartz porphyry.
Mt. Amram, Southern Negev.
- D** Talus slopes at the foot of a large scarp. The taluses are composed of debris flow, rockfall and washed grus deposits. The bedrock lithology is coarse crystalline granite.
Santa Katarina area, southern Sinai.
- E** Talus slopes, composed of debris flow and rockfall deposits:
(1) An active talus.
(2) A talus relict mantled by talus Reg soil. Bedrock lithology is flint and marl layers (Sayarim Formation) overlying chalks (Menuha Formation).
Southern Arava Valley margins.
- F** Talus slopes composed primarily of debris flow deposits.
Note recent debris flows on the upper part.
Wadi Mukeibila, eastern Sinai



PLATE 9

Densely dissected and badland terrains:

- A** Loess and loessial soils in the southern coastal plain in Israel.
- B** Chalks and shales of the Lisan Formation in the northern Arava Valley.
- C** Marls and shales in the Zin Valley, northern Negev.
- D** Chalks overlain by flint, northern Negev.

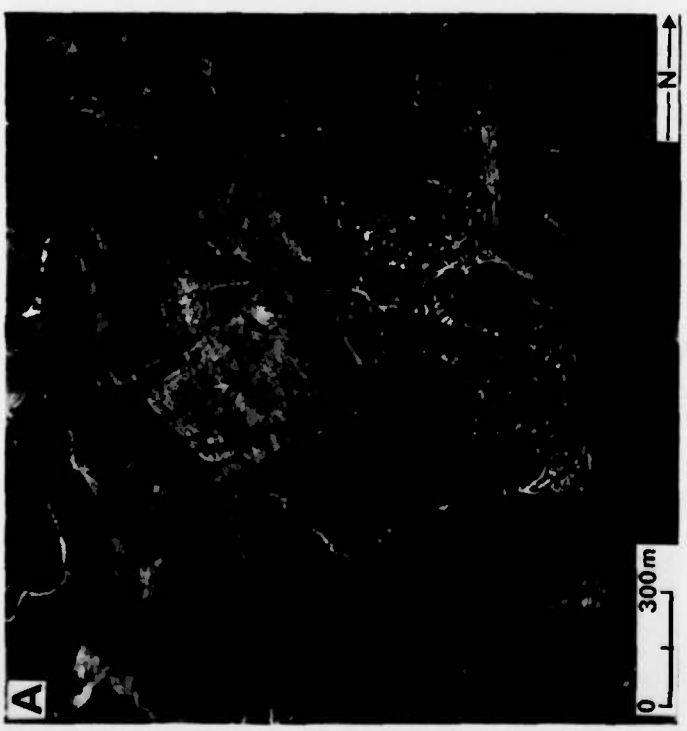
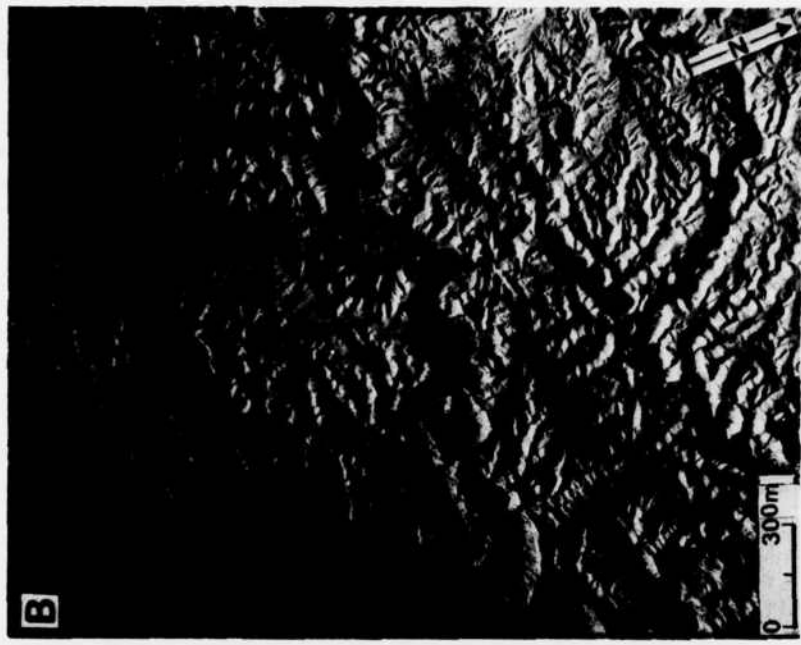


PLATE 10

- A** Round structures of an archaeological site of Middle Bronze I Age (-4000 years old). The structure is partly filled with eolian dust.
Nitsana Site, western Negev.
- B** A cut in a Middle Bronze I house, partly filled with eolian dust and collapse stones.
Be'er Rassisim, western Negev.
- C** A cut in a dust and gravel fill of an Early Bronze archaeological site (-4500 years old).
Tel Arad, northern Negev.
- D** Stratified fluvial loess and gravel fill behind a dam.
Western Negev.

A



C

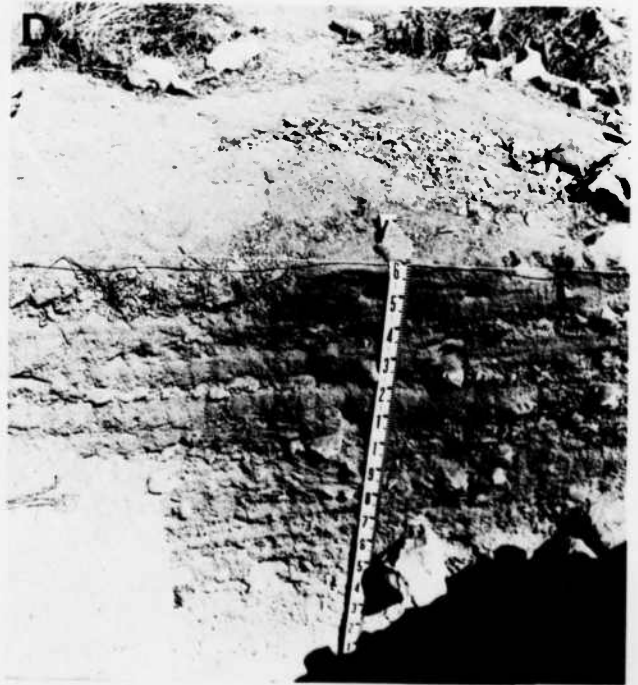


PLATE 11

- A** A well developed Hammada soil on a limestone plateau. A complete cover of desert pavement overlying a gravel-free B horizon.
Southern Negev
- B** A Hammada soil profile on a quartz porphyritic bedrock. A complete, well developed, desert pavement cover; a silty vesicular A horizon (1 cm thick); the C horizon (30 cm thick) is composed of mechanically weathered gravel, with highly saline and gypsyferous silty sand (including gypsic gravel coatings).
Mt. Amram, southern Negev.
- C** A young Takyr soil in the southern Negev, composed of silt-loam.
- D** A Pleistocene Reg soil in eastern Sinai: a gravel-free B horizon and a highly gypsi-ferous and saline C horizon. Note the gypsic pebble coatings.

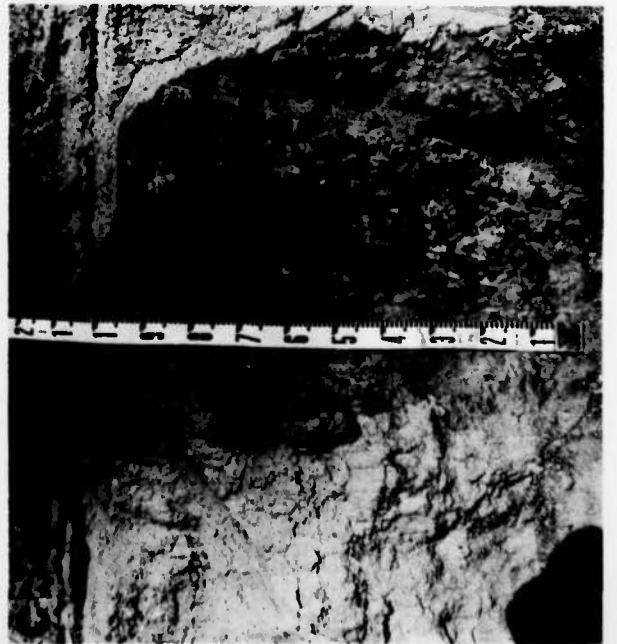
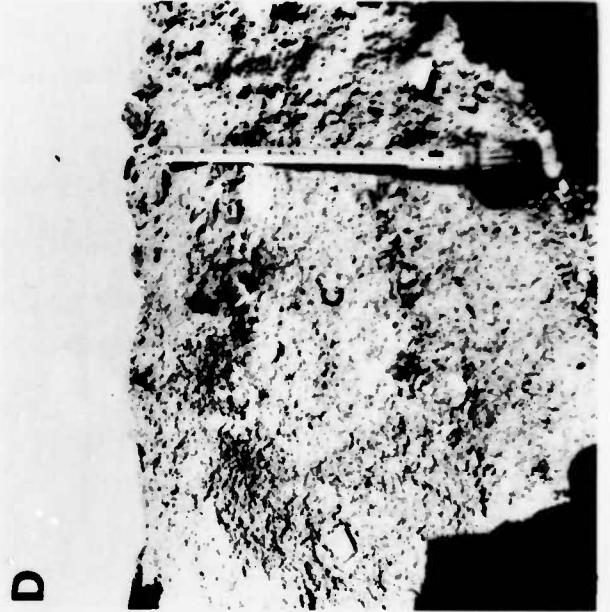
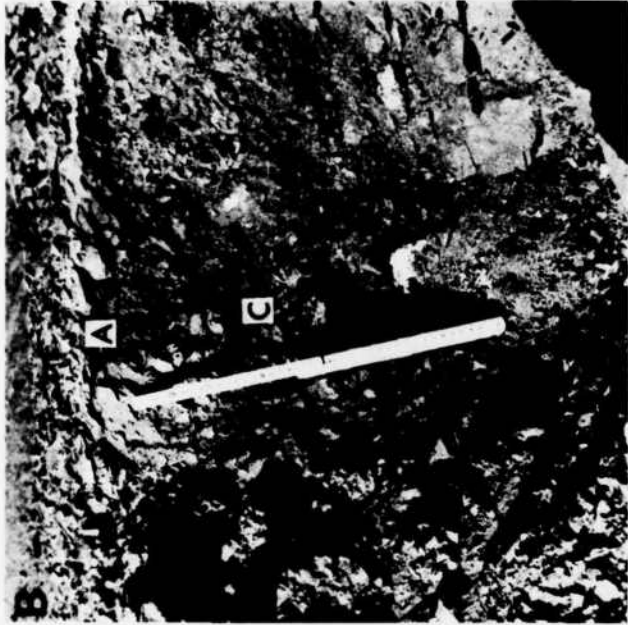
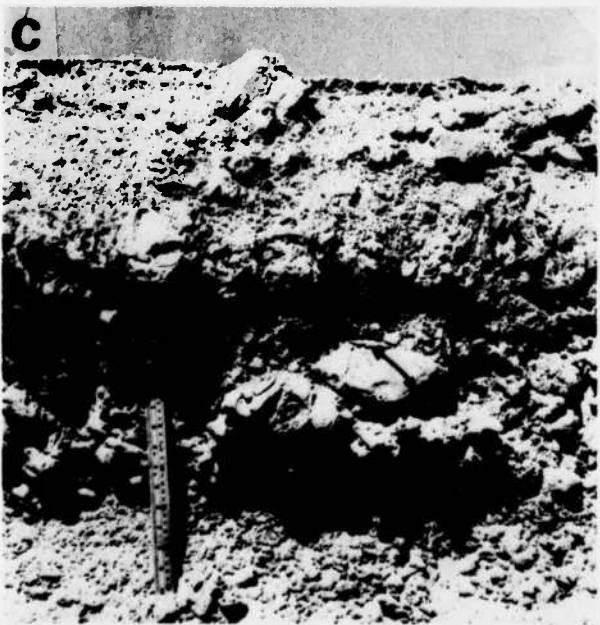
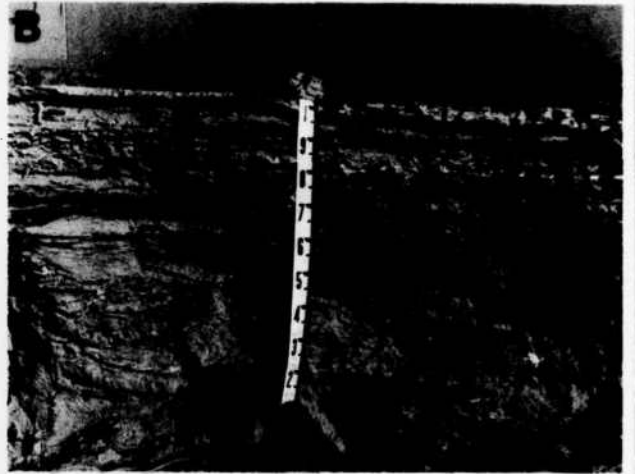
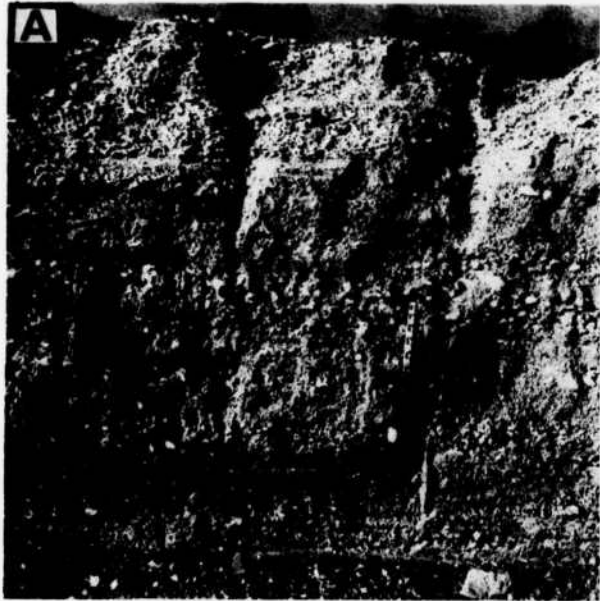


PLATE 12

- A** Stratified alluvium in a Holocene terrace, composed of gravel and sand.
Mt. Amram, southern Negev.
- B** Stratified and cross-bedded fluvial (1) sands and (2) silty loams.
East of Yotvata, southern Arava Valley.
- C** Gypsum coating of cobbles in a Pleistocene Reg soil.
Timna Valley, southern Negev.
- D** Discontinuous gypsum coating on gravel in the C horizon of a latest Pleistocene -
early Holocene Hammada Soil.
Mt. Amram, southern Negev.



3

PLATE 18

- A An early Holocene Reg soil: a locally well developed desert pavement overlying a thin vesicular silt-loam A horizon (0.5 cm thick). B horizon is gravelly and slightly saline. C horizon is highly gravelly, gypsiferous and saline. Note the mechanically weathered gravel in the C horizon.
Nahal Ze'elim, western Dead Sea.
- B An early Holocene Reg soil in Timna Valley, southern Negev. The vesicular A horizon is 1.0-1.5 cm thick; B horizon is 5-10 cm thick and highly silty; C horizon is gypsiferous and saline, with a high proportion of salt weathered gravel.
- C A Pleistocene Reg soil on a high terrace of Wadi Sa'ade, eastern Sinai. Note the difference between the highly gypsiferous right hand side and the far less gypsiferous left bank side of the C horizon.
- D An old polygenetic Reg soil on a late Tertiary surface. A thick layout gravel-free silt loam A and B horizons, is overlain by a well developed desert pavement. Paleocalcic and paleogypsic horizons are observed below depth of 70 cm.
- E A late Pleistocene Reg soil with a petrogypsic horizon in the southern Arava Valley.
- F A mottled calcic paleosol burried under a later loessial cover in Nahal(=wadi) Nitsana, western Negev.

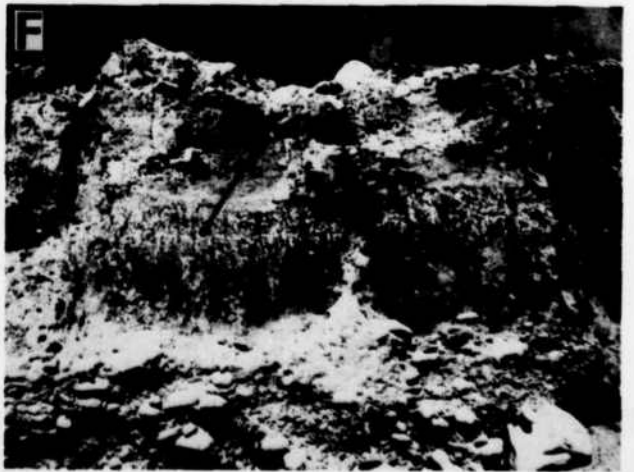
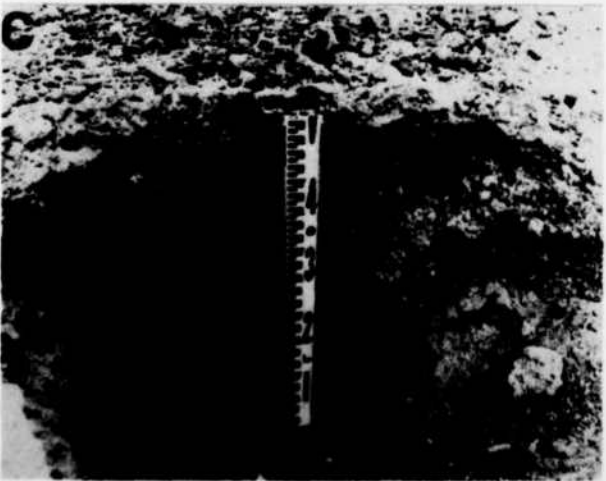
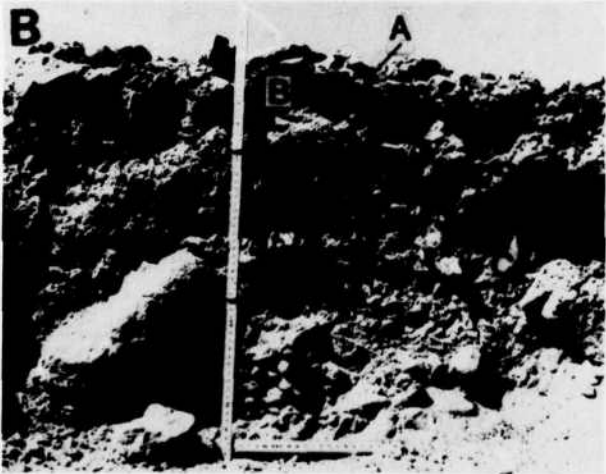


PLATE 14

- A** A gravelly surface of an early Holocene alluvial fan. An early stage of desert pavement development.
Wadi Mukeiblla, eastern Sinai.
- B** A well developed desert pavement.
Nahal (=wadi) Nitsana, western Negev.
- C** Plates of sandstone over sand and bedrock.
Southern Sinai.
- D** A typical Hammada surface:
(1) Limestone bedrock, in situ.
(2) Desert pavement over Hammada soil in pockets.
Western Negev.



PLATE 15

- A** Encrusted debris mantle on shales. The crust is composed of 60-70% clay, 30-40% silt, and minor amounts of fine sand (< 5%).
Northern Negev.
- B** Fine angular gravel is sieve deposited in an active alluvial fan.
Mt. Amram, southern Negev.
- C** A loamy crust deposited on an active floodplain.
Biq'at Uvda, southern Negev.



APPENDIX 2 FIGURES

Note: The figure numbers and the captions are those presented in the accompanying report. The user may find detailed explanations in the text accompanying these figures.

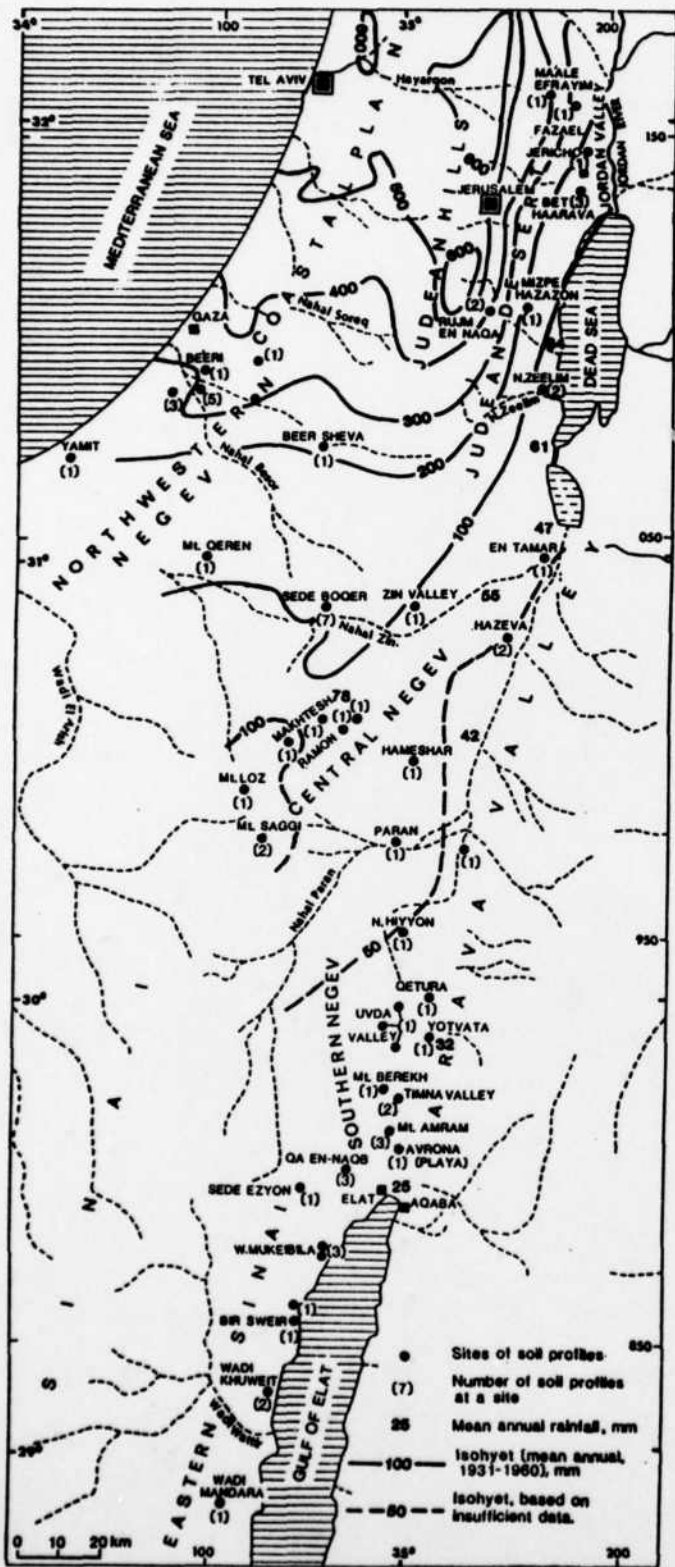


Figure A.1 A location map — The Negev, northeastern Sinai, part of the Dead Sea Rift Valley and the Judean Desert: mean annual rainfall and sites of soil profiles and sections in surficial deposits.

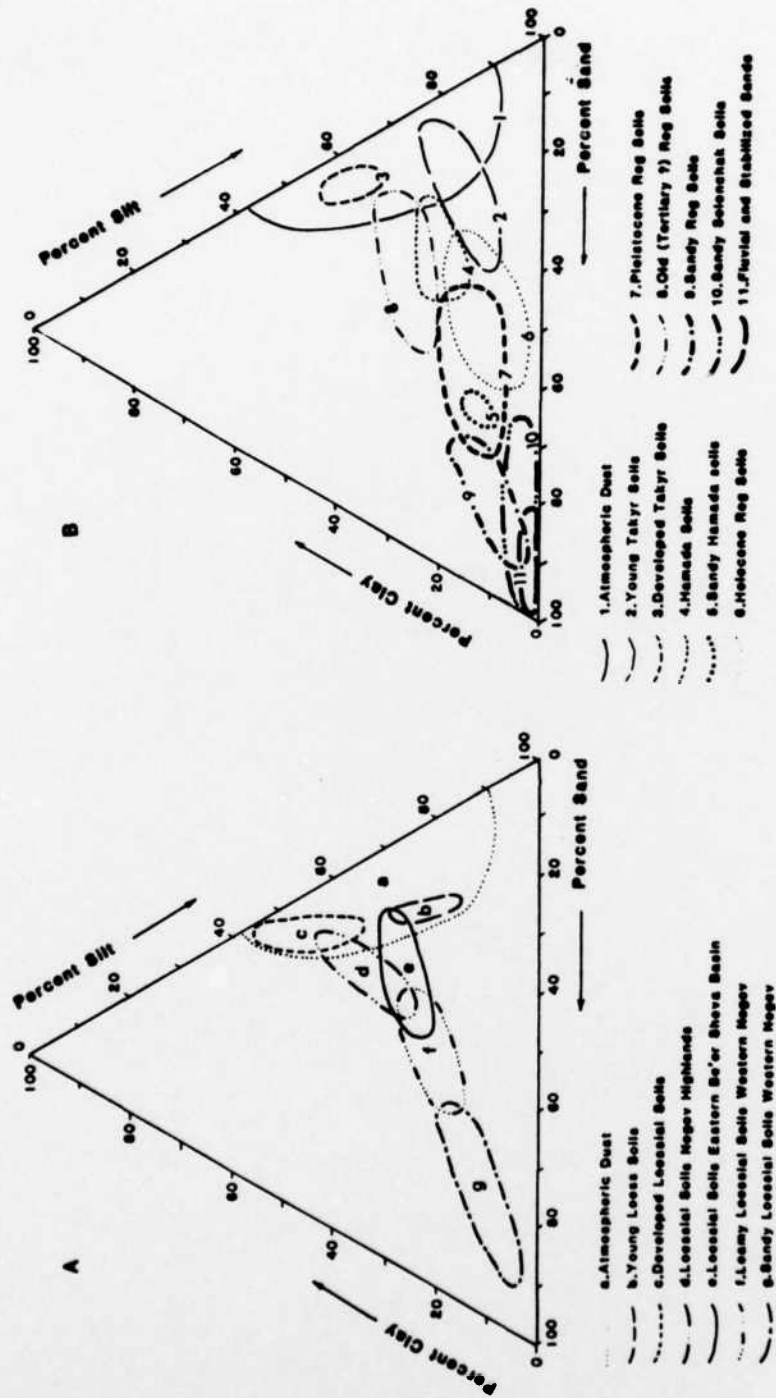


Figure C.1.1. A. The general textural composition of loess and loessial soils in the semi-arid to arid parts of Israel (the northern and northwestern Negev) see Fig. 1C for textural definitions.

B. The general textural composition of soils in the desert environments in Israel and the Sinai Peninsula (see fig. 1C for textural definitions).

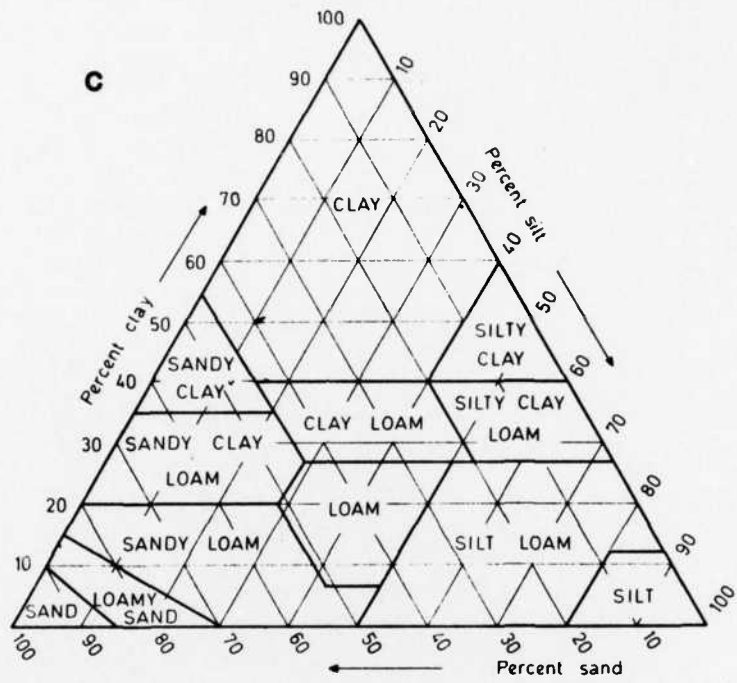


Figure C.1.1, Continued C. Textural definitions of soils.

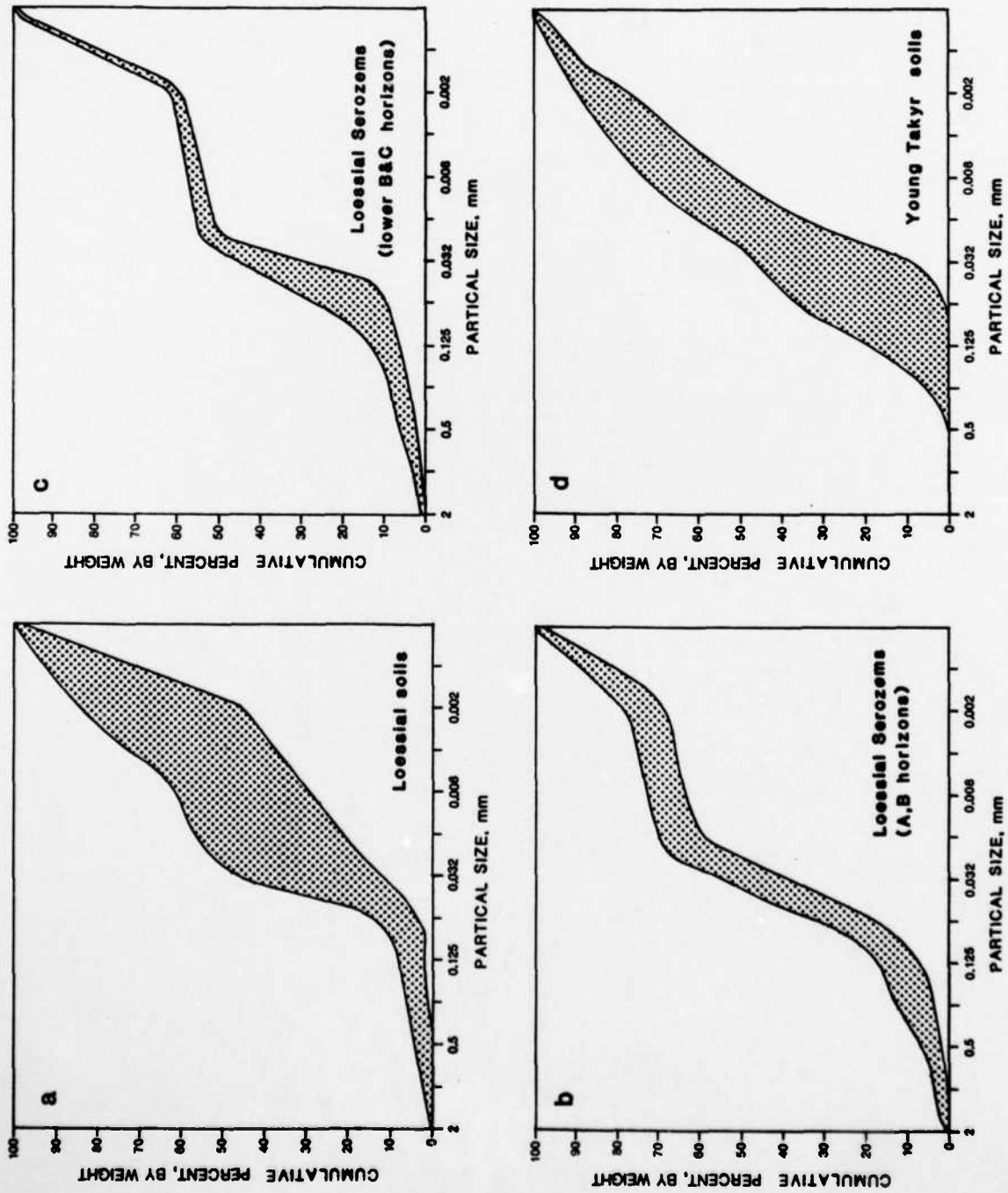


Figure C.1.2. Particle size distributions in aridic soils in Israel and Sinai. The ranges of the frequently encountered distributions are presented.

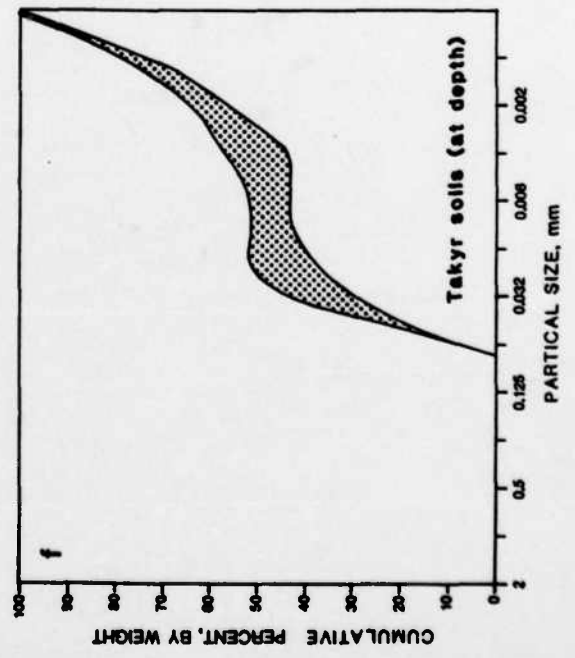
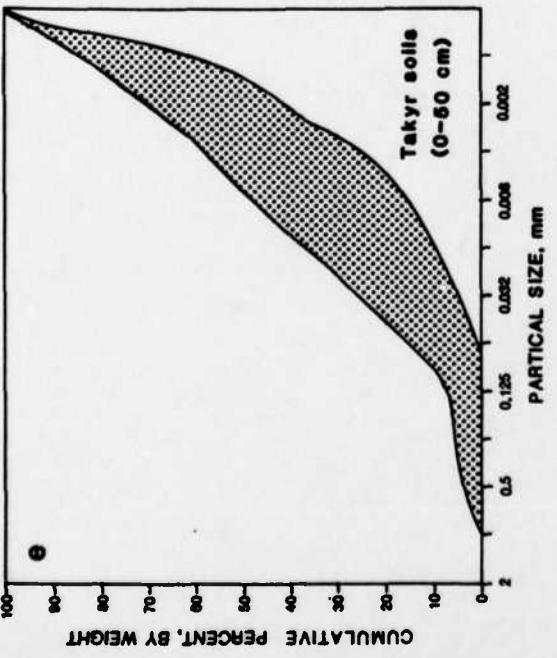
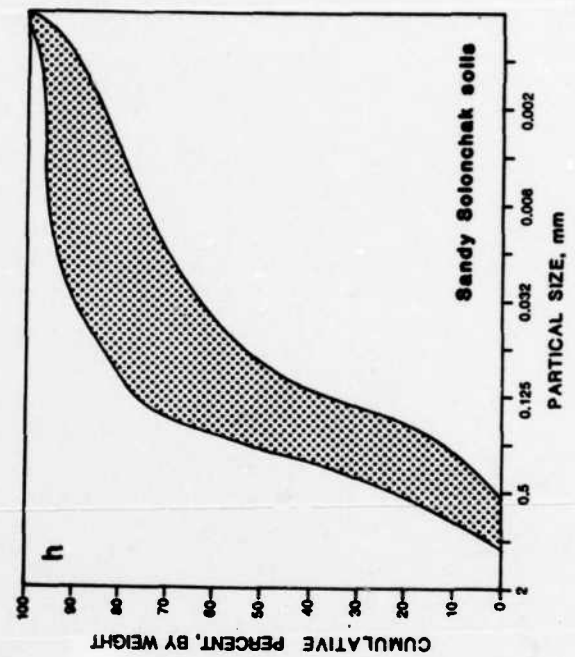
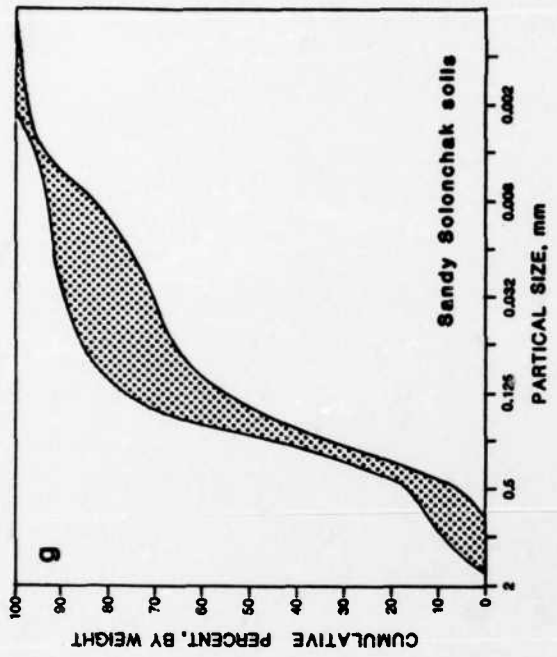


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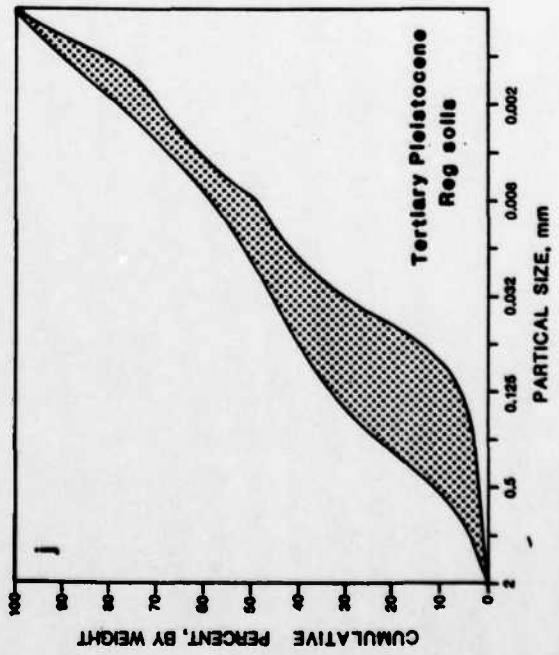
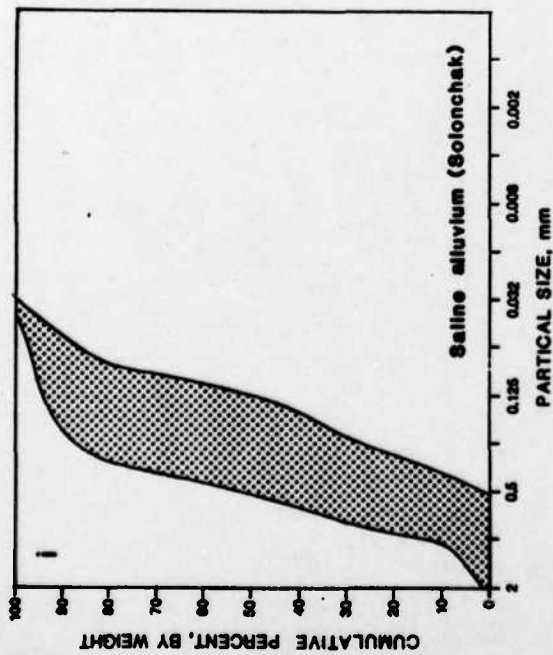
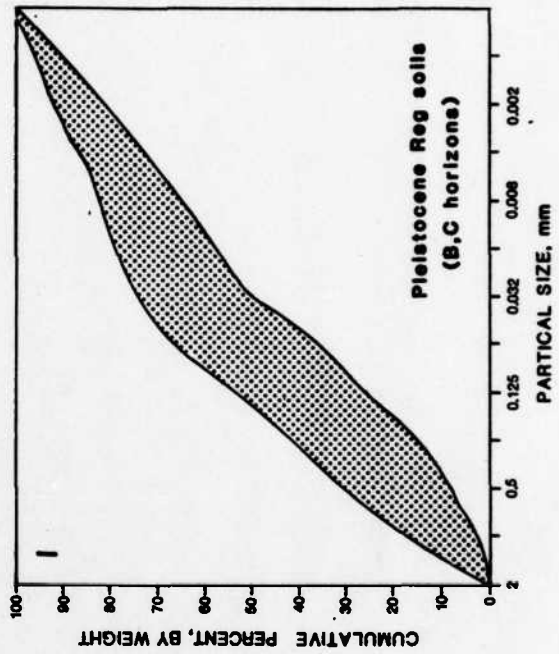
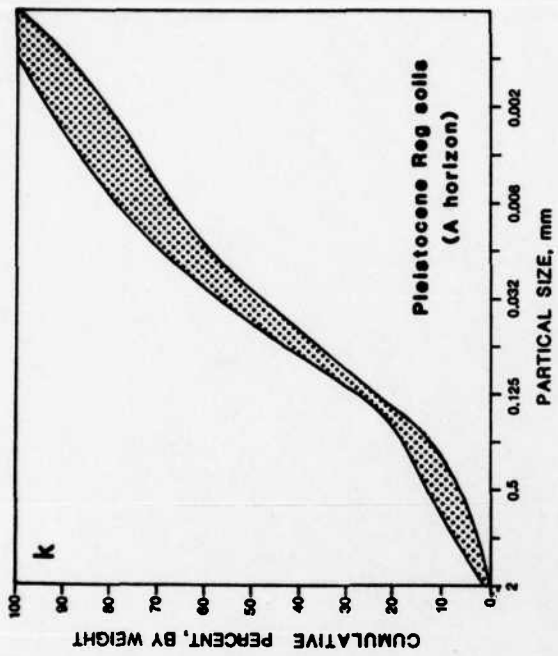


Figure C1.2, Continued

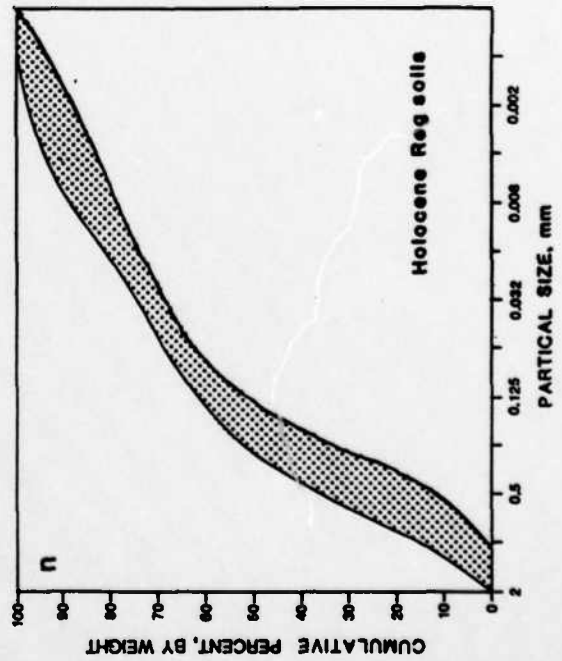
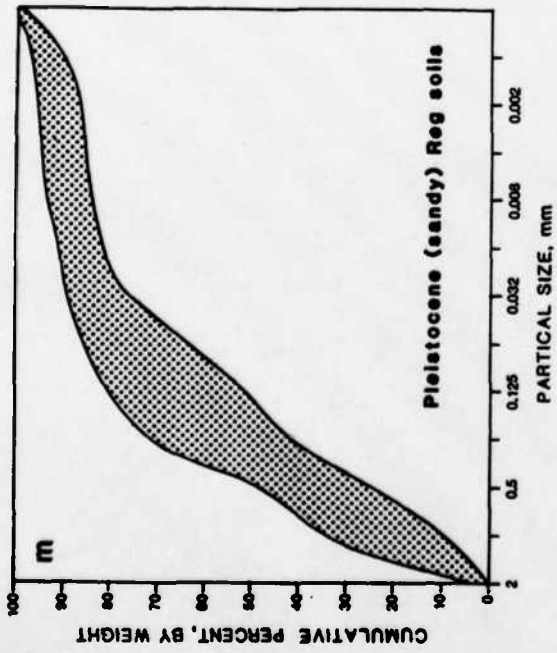
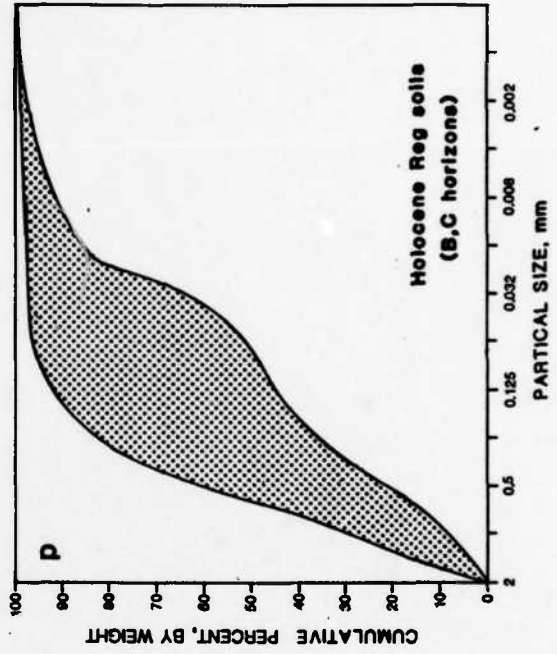
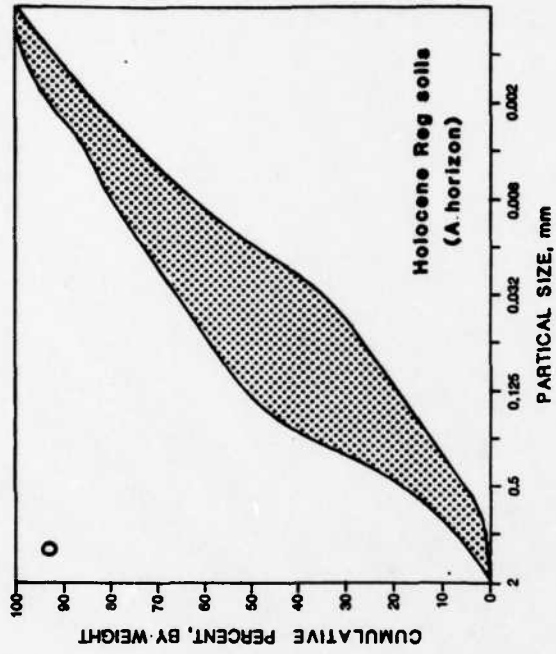


Figure C.1.2, Continued

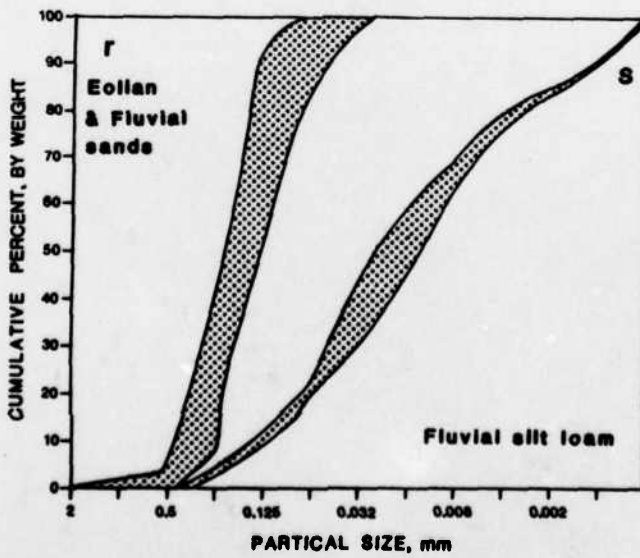
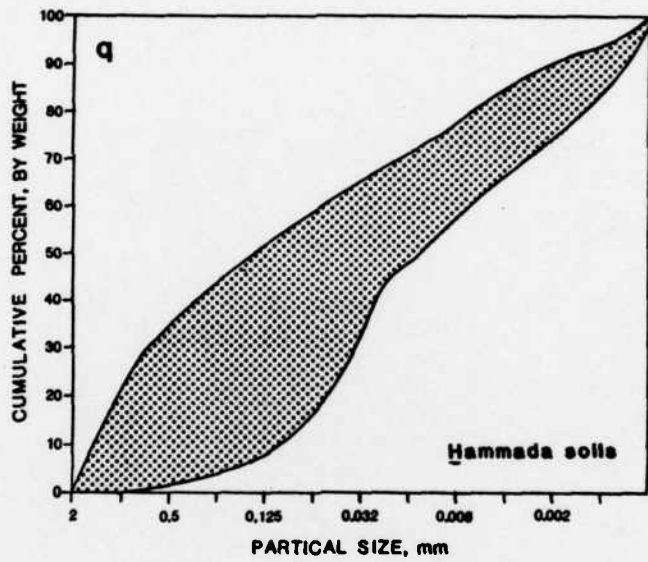


Figure C.1.2, Continued

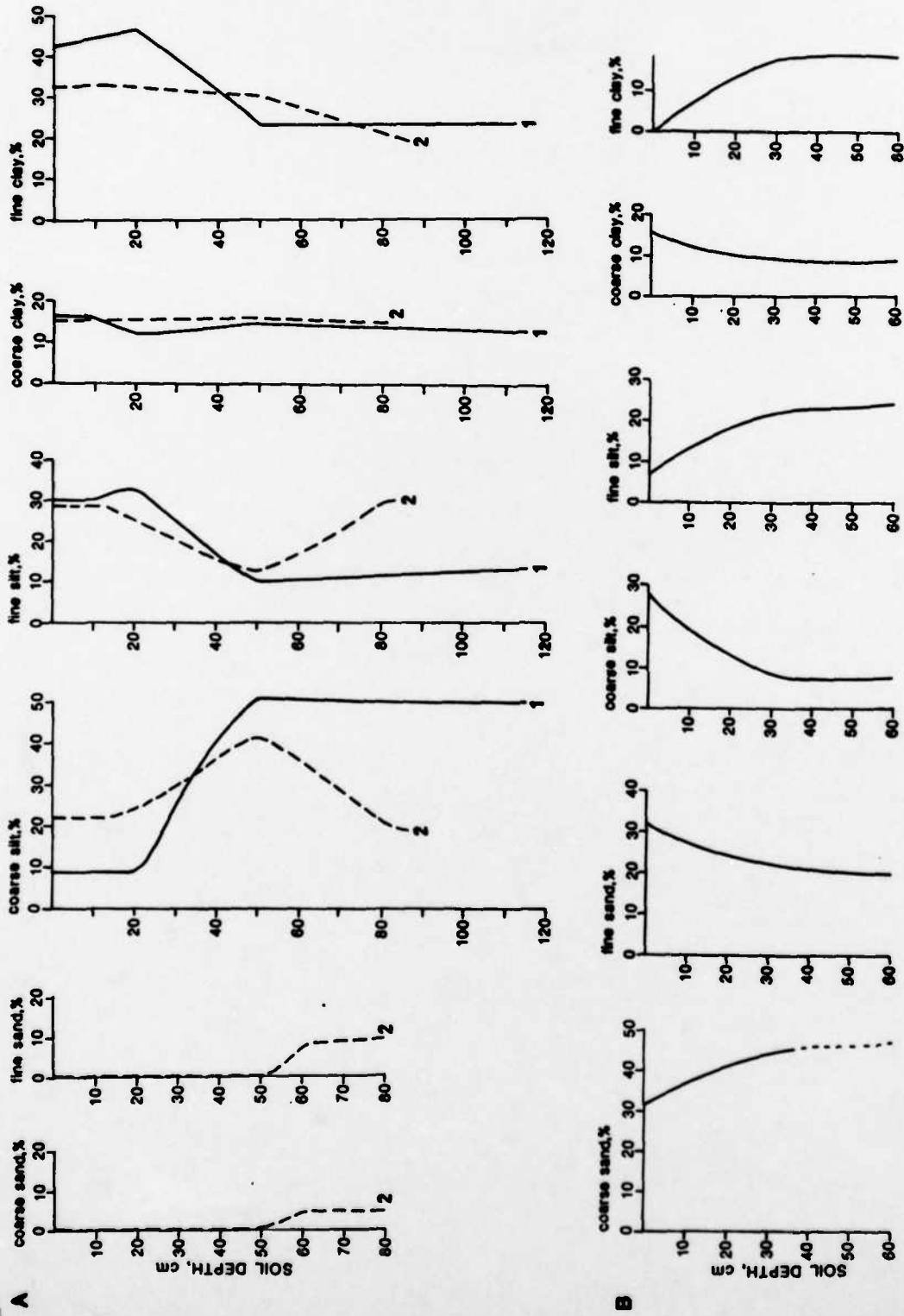


Figure C.1.1. A. Texture, by size fractions with depth, of two Takyr soils in Qa en Naqb, west of the Eilat mountains, southern Negev. 1. Center of the plays. 2. The margins of the central plays zone. The finer fractions are more abundant in the upper 0.5 m of the soil profile in the central plays zone.

B. Texture by size fractions with depth, of a sandy Solonchak soil, Bir Sweir, eastern Sinal.

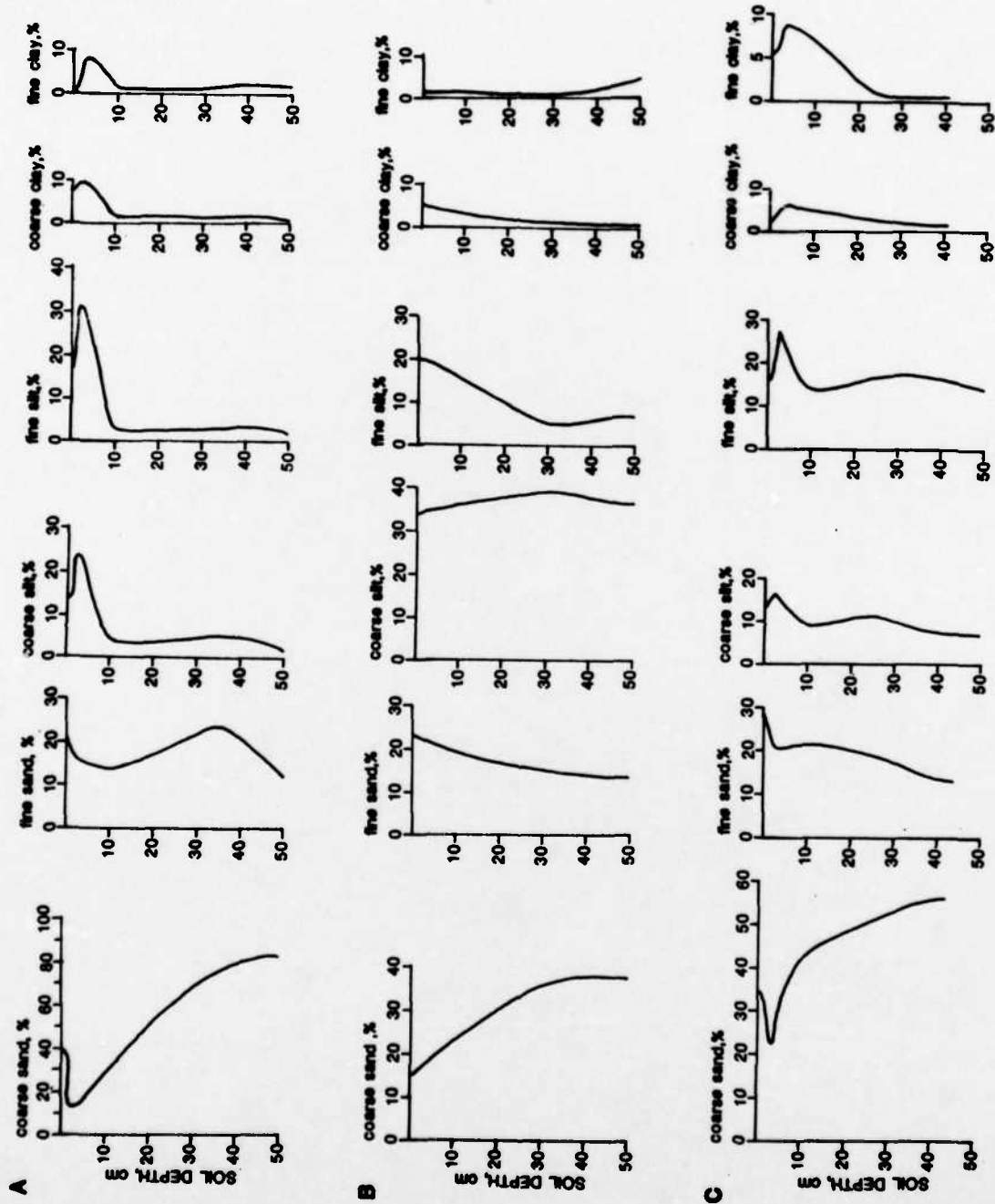


Figure C.1.6. Distribution of size fractions with depth, in Reg soils on early Holocene alluvial surfaces in Wadi Muqeibilia, eastern Sinai (A,B) and Timna valley, southern Negev (C).

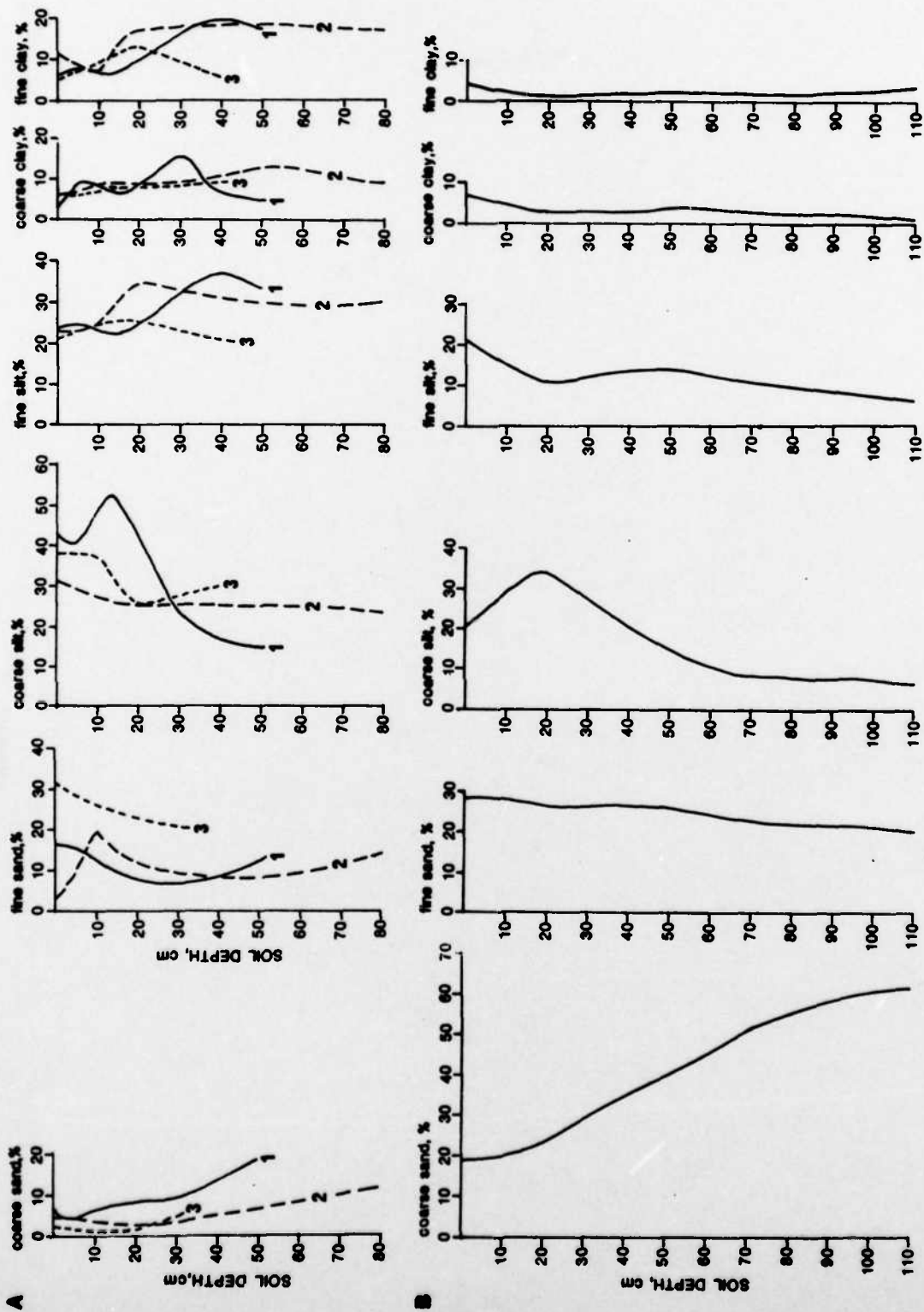


Figure C.1.7. Distribution of the various size fractions with depth, in Reg soils on Pleistocene alluvial surfaces: A. Three soil profiles in the Zin Valley, central Negev. B. A soil profile in the Timna Valley, southern Negev.

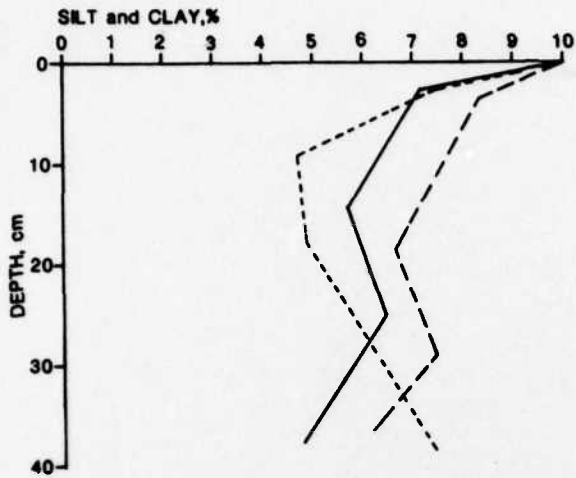


Figure C.1.11. Silt and clay content with depth, in stabilized dunes in the western Negev (from H. Tsor, unpublished).

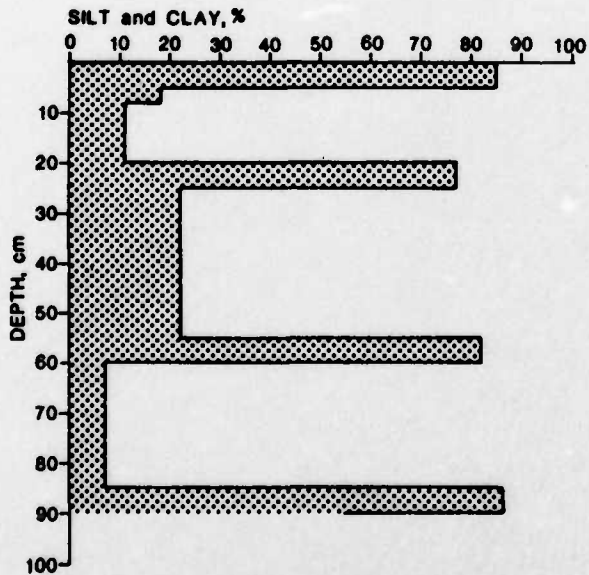


Figure C.1.12. Silt and clay content in a flood plain of a stream channel crossing a sand field near Yotvata, southern Arava Valley. The remaining material is sand (see a photograph in Plate 12B).

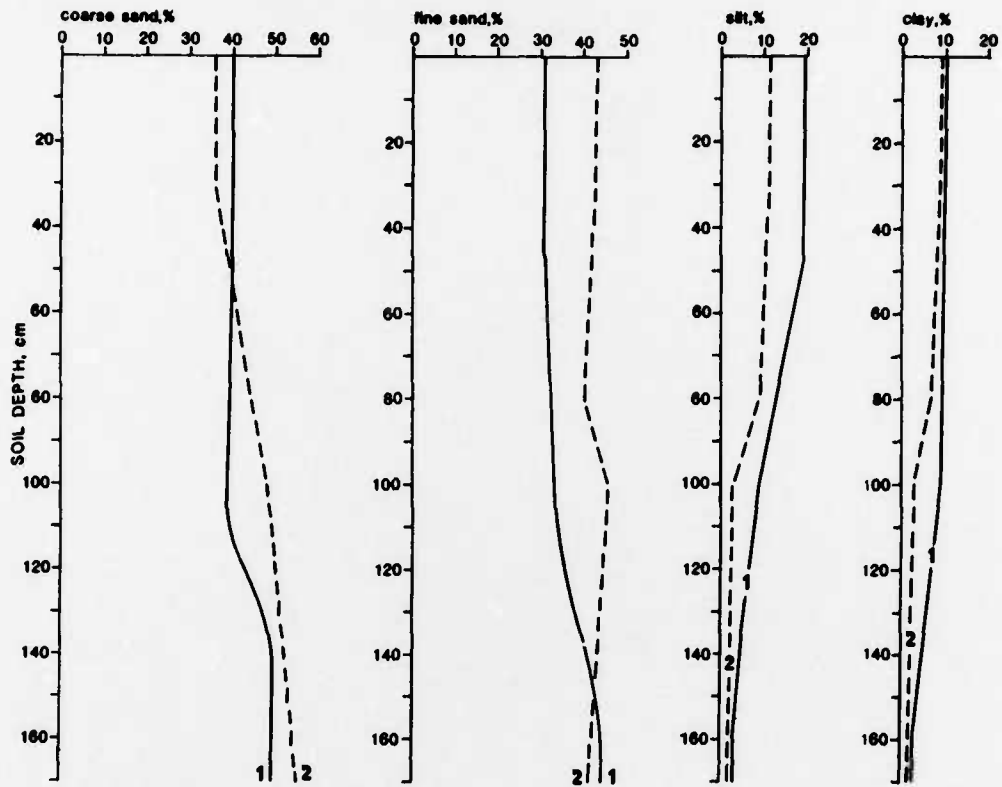
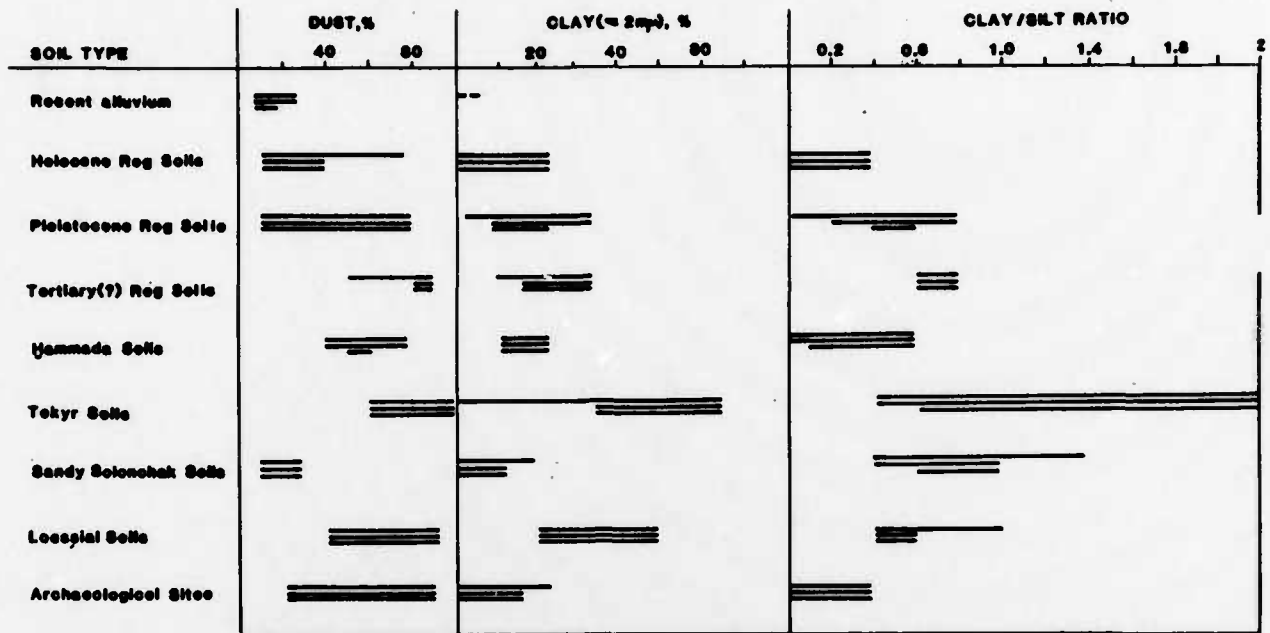
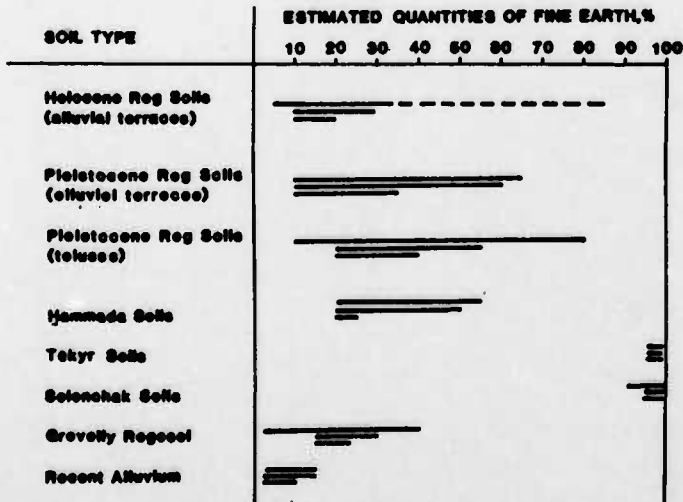


Figure C.1.13. Size distribution by fraction, with depth, in sandy soils in Western Negev: 1. Be'eri 2. Kissufim. (data from Marish et al., 1978)



very frequent =====
 frequent =====
 not frequent =====
 rare -----

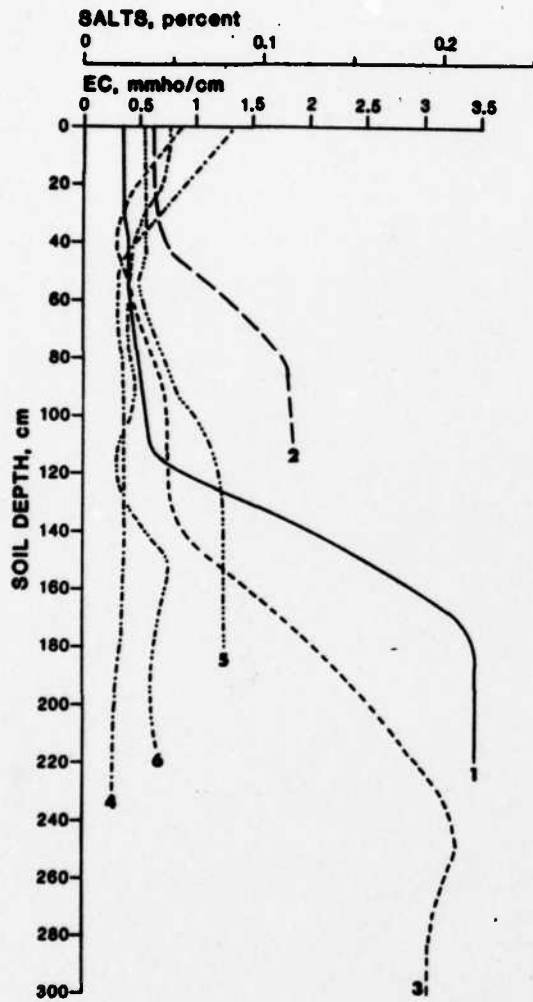
Figure C.1.16. Dust content, clay content and clay / silt ratios in various aridic soils - general frequency of occurrence.



very frequent =====
 frequent =====
 not frequent =====
 rare -----

Figure C.1.17. Estimated quantities of fine earth (<2 mm in size), percent, in various desert soils.

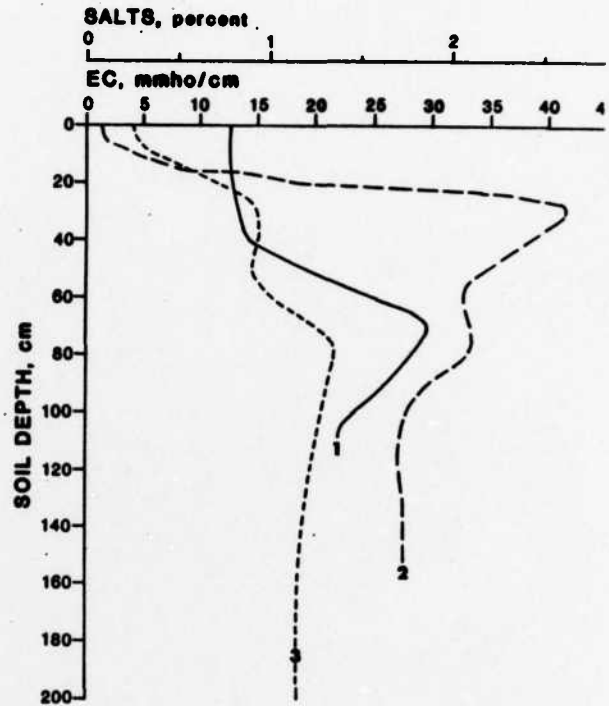
Loessial soils



- 1. Jordan Valley
- 2. North Western Negev
- 3-6. Western Negev

Figure C.3.1 The content of salts in Loessial soils of the Jordan Valley, western and northwestern Negev.

Loessial Serozems



- 1, 2. Sde Boker
- 3. Be'er Sheva

Figure C.3.2 The content of salts in Loessial Serozems, western Negev.

Takyr soils

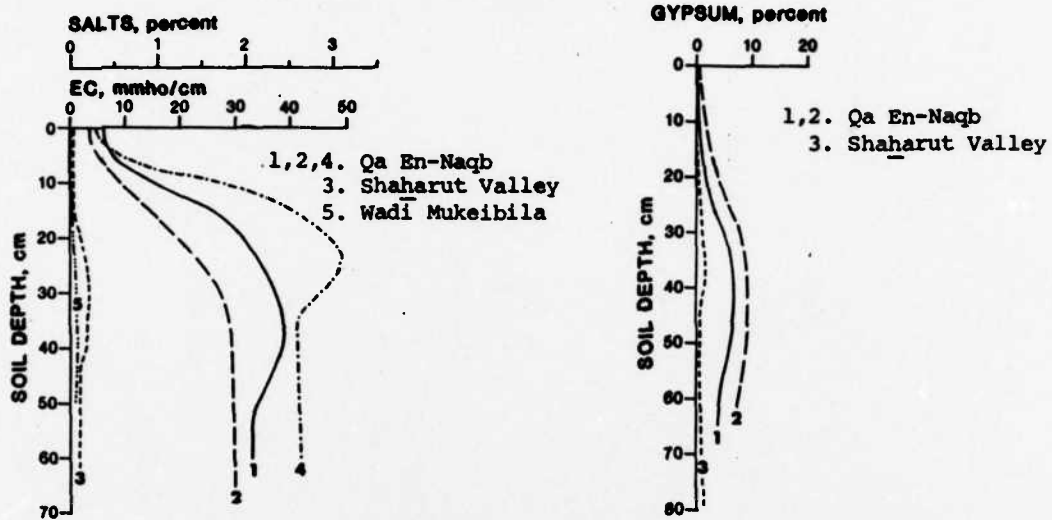


Figure C.33 The content of salts and gypsum in Takyr soils in the southern Negev and eastern Sinai.

Solonchak soils

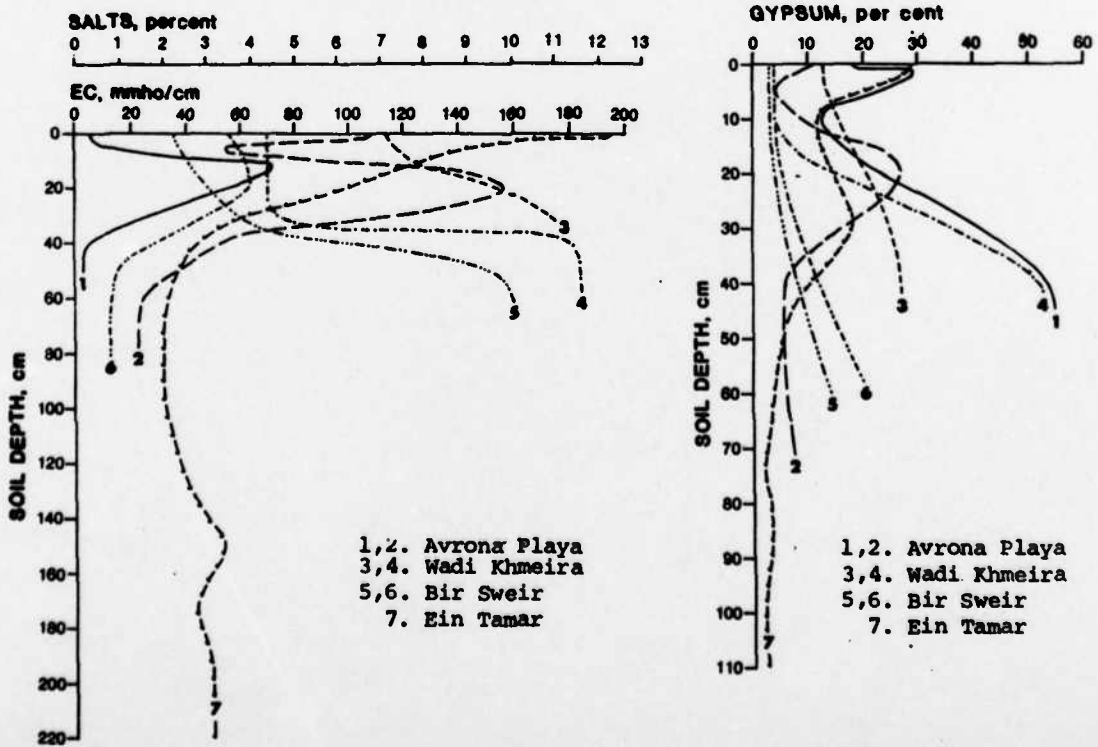


Figure C.34 The content of salts and gypsum in Solonchak soils in the Arava valley and eastern Sinai.

Holocene Reg soils

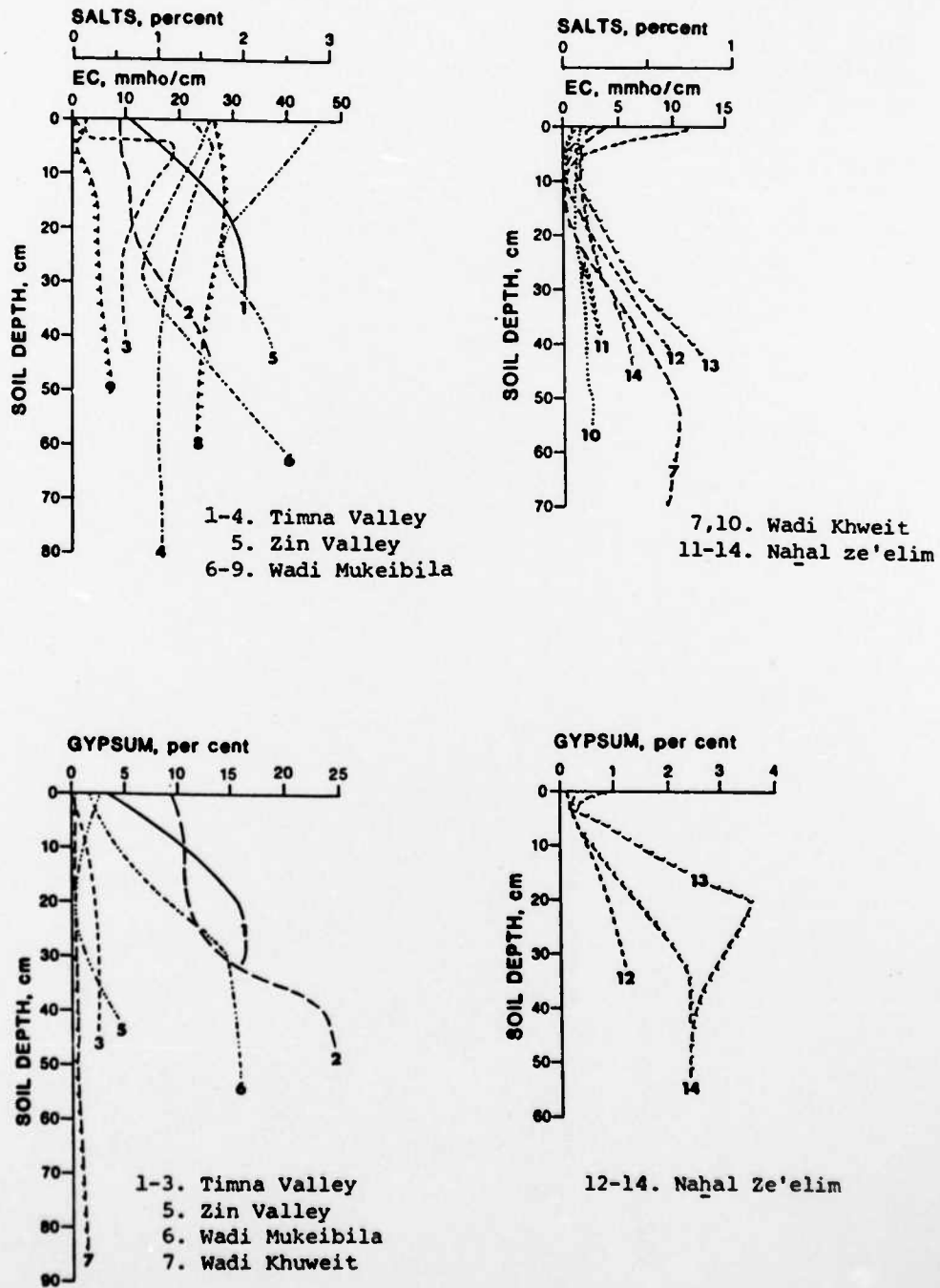


Figure C.3.5 The content of salts and gypsum in the fine earth fraction of some Holocene Reg soils, in the Dead Sea region, Arava Valley, Zin Valley and eastern Sinai.

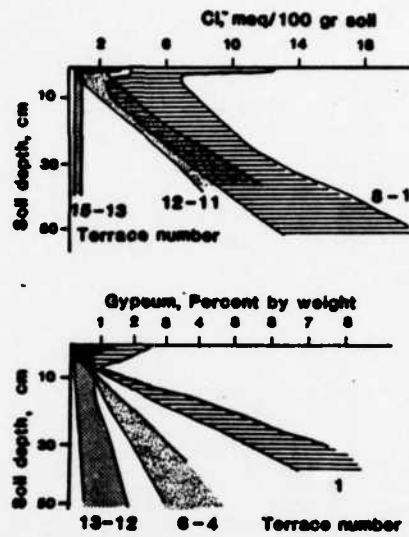


Figure C.3.6 Variation of gypsum and chlorides with depth, in a sequence of Holocene Reg soils (terrace no. 1 - oldest; terrace no.15 - youngest), Nahal Z'elim (Dead Sea).

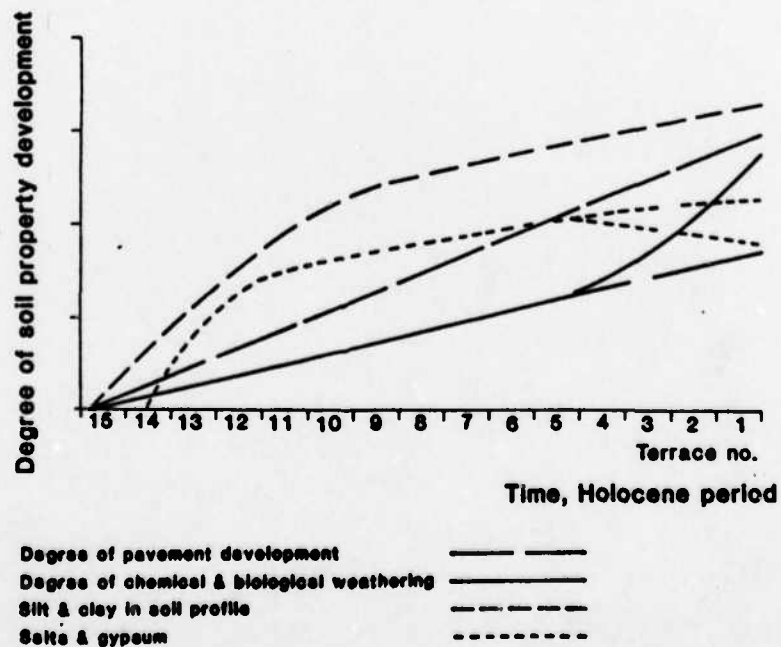


Figure C.3.7 The evolution of some properties of Holocene Reg soils with time (terrace no.1 - oldest; terrace no.15 - youngest), Nahal Z'elim (Dead Sea).

Pleistocene Reg soils

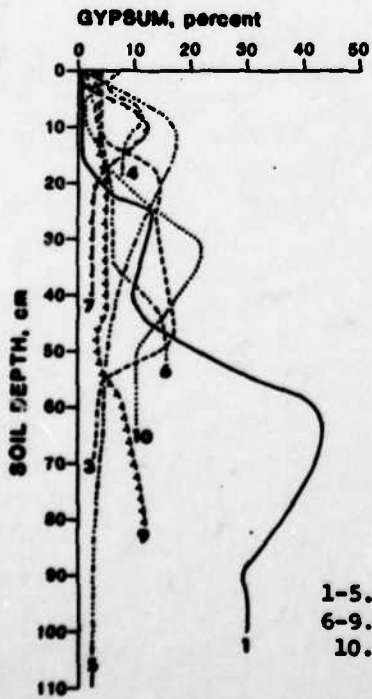
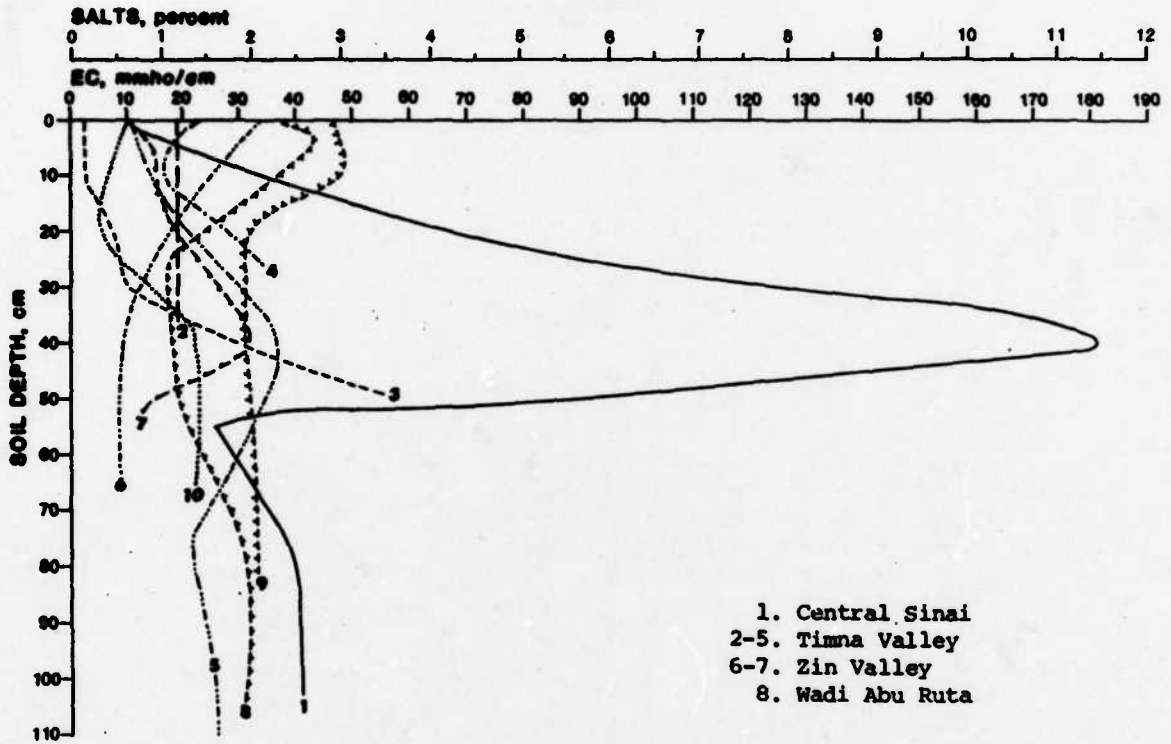


Figure C.3.8 The content of salts and gypsum in the fine earth fraction of Reg soils on Pleistocene alluvial surfaces in the Negev and eastern Sinai. Curve no.1 is typical to Reg soils on early Late Pleistocene and older alluvial surfaces (see plate 13E).

Hammada soils

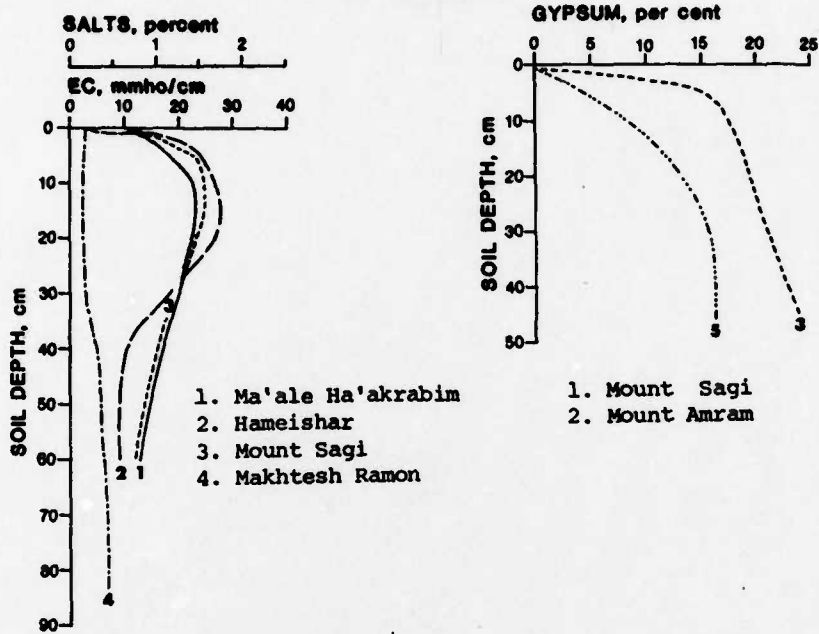


Figure C.3.12 The content of salts and gypsum in the fine earth fraction in some Hammada soils in the northeastern and central Negev.

Lithosols

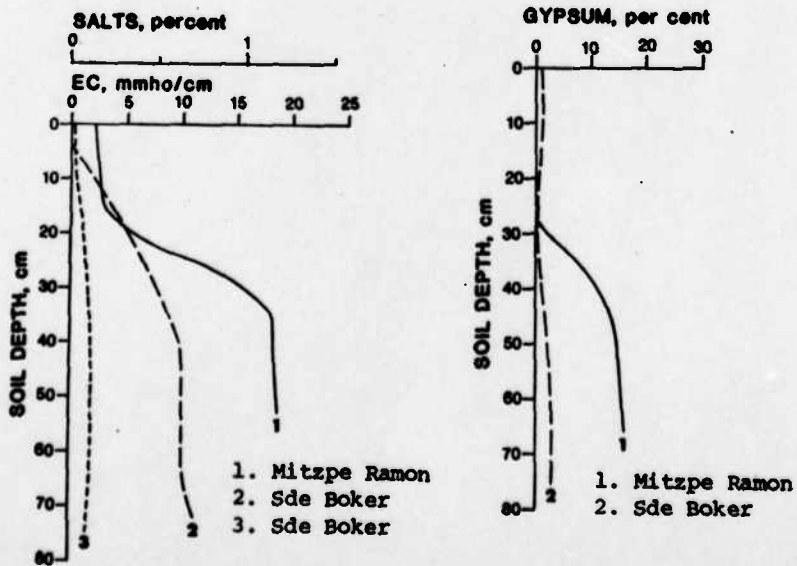
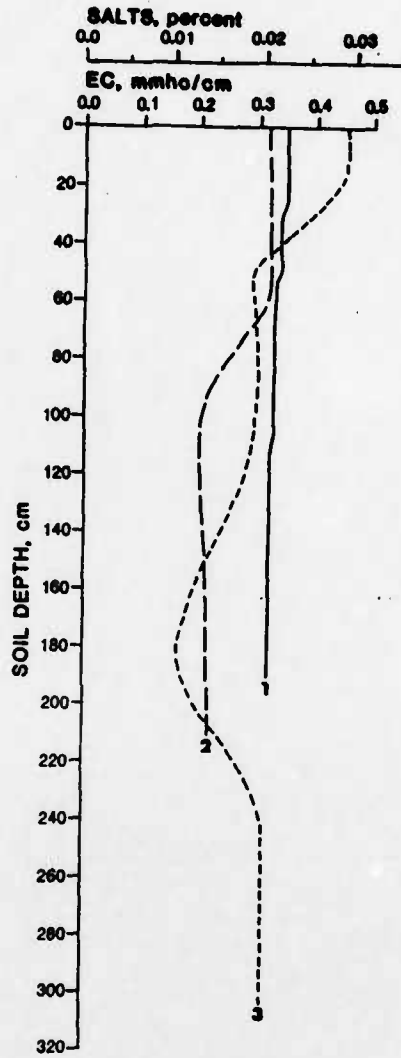


Figure C.3.13 The content of salts and gypsum in Lithosols in the northern and central Negev.

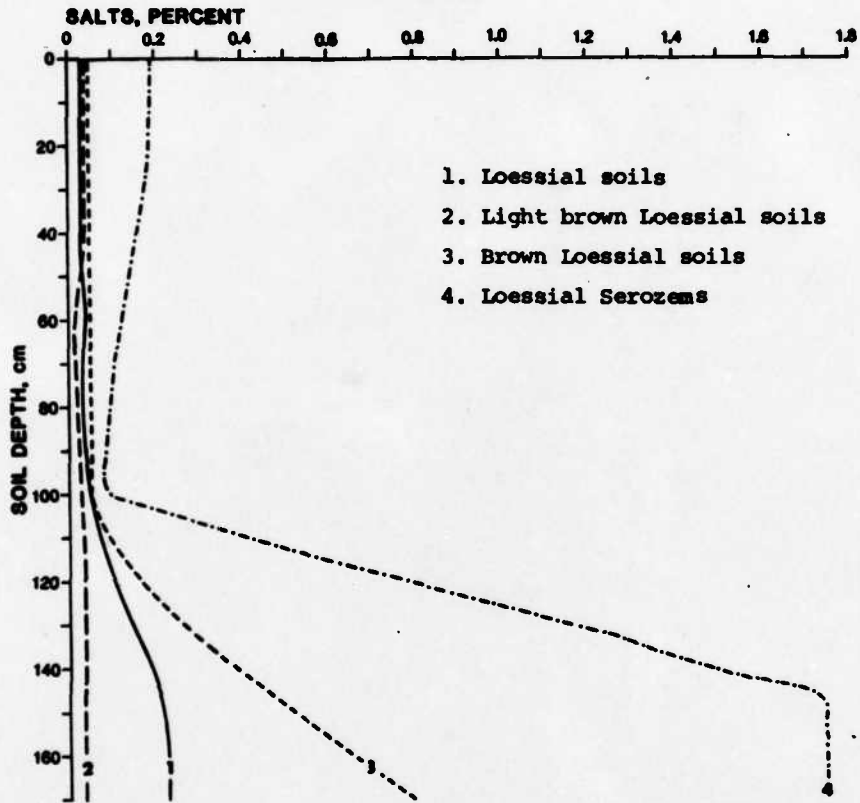
Dune soils



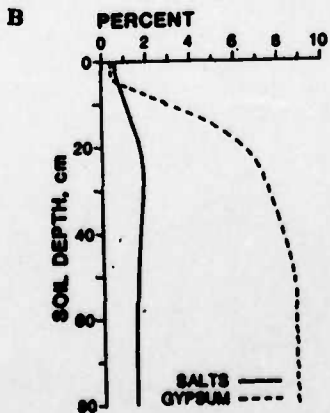
1-3. Northwestern Negev

Figure C.3.15 The content of salts in dune soils in the northwestern Negev.

A Loessial soils



Reg soils (no age assigned)



C Reg soils

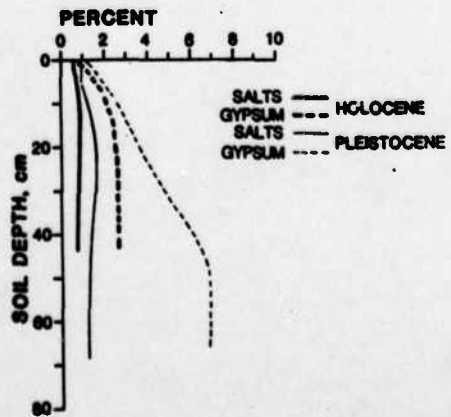
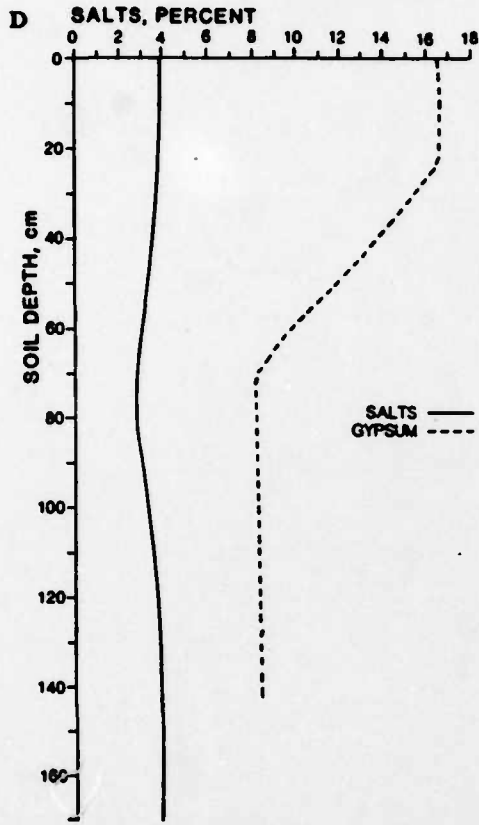
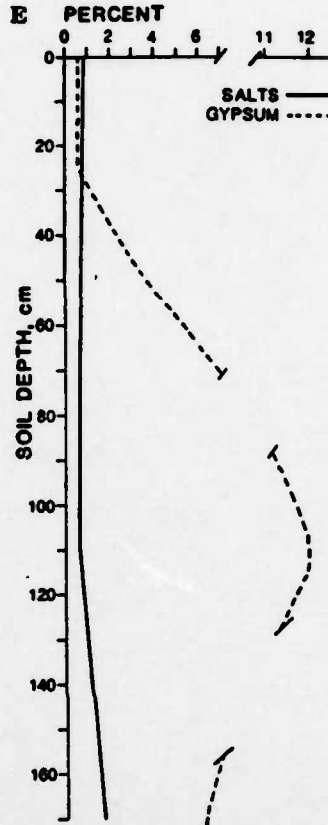


Figure C.1.23 The average content of salts and gypsum in various aridisols.

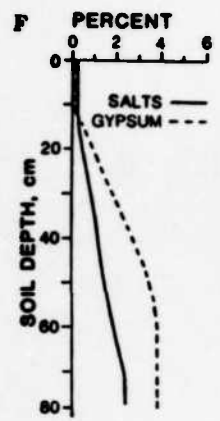
Solonchak soils



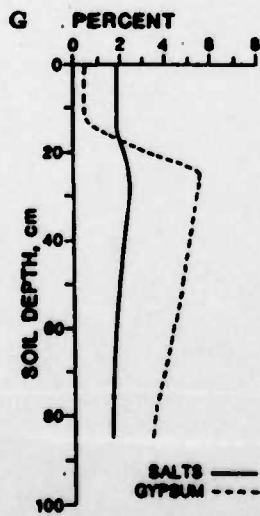
Serozem soils



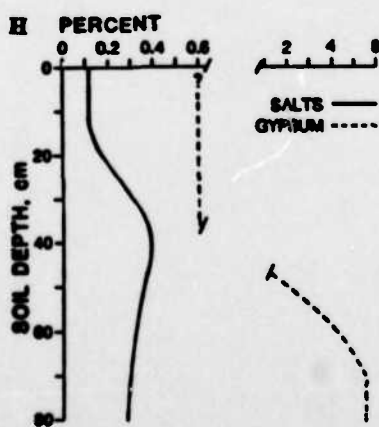
Gravelly Regosols



Takyr soils



Lithosols



Hammada soils

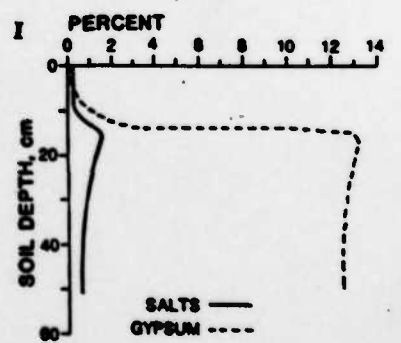


Figure C.3.22, Continued

APPENDIX 3 GLOSSARY

Note: The following terms are defined for application in the context of the present report. In some cases the definitions are not sufficient for general use. The emphasis here is on terrains of the hot deserts.

- Acid Volcanic Rocks** Igneous rocks that have been poured out or ejected at or near the earth's surface, having a higher percentage of silica than orthoclase, the limiting figure commonly adopted being 60%.
- Aggregate** A group of primary particles intimately bound such that they form secondary units.
- A Horizon (in desert soils)** A mineral soil horizon formed at or adjacent to the surface.
- Alluvium** An unconsolidated sediment deposited by a stream or a river (a fluvial sediment). Composed of gravel, sand, silt, clay.
- Badlands** An extremely dissected landscape, characterized by very fine drainage network, usually carved in unconsolidated or poorly cemented materials such as silt, clay, shale, chalk, volcanic ash. Lack of vegetation, steep gradients and erodible materials are favorable environmental conditions for badland formation.
- Bajada or Bahada** The nearly flat surface of a continuous apron consisting of confluent alluvial fans which together with the pediment make up the piedmont slope in a basin.
- Ballena** A major landform comprising distinctively round topped ridgeline remnants of fan alluvium. The ridge's broadly rounded shoulders meet from either side to form a narrow crest and merge smoothly with the concave backslopes.
- Basalt** A general term for dark colored mafic igneous rocks, commonly extrusive but locally intrusive, composed chiefly of calcic plagioclase and clinopyroxene; the fine grained equivalent of gabbro.
- B Horizon (in desert soils)** A mineral soil horizon in which the parent sediment or rock structure and texture has distinctly changed, characterized by: (a) an illuvial concentration of silt, clay and occasionally fine sand; (b) weathering of certain minerals and iron released as oxides/hydroxides; (c) some new structure has formed; (d) usually shows accumulation of salts, gypsum or carbonate.
- Brown Alluvial Soil** A brown soil formed of young alluvial deposits in valley floors. The texture is loamy and often contains CaCO_3 .
- Brown and Light Brown Loessial Soils** A soil formed of eolian or fluvial loess usually with an AB_{ca}C or an AB_{ca}B_b profile. The texture is sandy-loam, loam or clay-loam. It contains CaCO_3 nodules throughout most of the profile.
- Buried Soil/Horizon** A soil or an horizon (B or C) is considered to be buried if there is a surface mantle or if it is overlain by a mantle of new material. (see palesol)
- ca-Calcic Horizon** A soil horizon with a secondary concentration of CaCO_3 of at least 5% by weight.
- Chalk** A very soft, white to light gray, unindurated limestone composed of the tests of floating microorganisms and

some bottom dwelling forms in a matrix of finely crystalline calcite. Some chalk can be almost devoid of organic remains.

C Horizon A mineral soil horizon or a layer underlying B horizon (q.v.), usually similar in structure and texture to the parent sediment or rock, but weathered and unconsolidated.

Clay A soil or sediment separate consisting of particles $< 0.002\text{mm}$ in (equivalent) diameter. Fine clay — $< 0.001\text{mm}$.

Climatic Regimes of the hot deserts are here subdivided accordingly to the mean annual precipitation as follows: (a) semi-arid — 400–250 mm/year; (b) moderately arid — 250–150 mm/year; (c) arid — 150–80 mm/year; (d) extremely arid — < 80 mm/year.

Colluvium Colluvium is the superficial mantle of unconsolidated rock debris which consists of heterogeneous materials of any particle size which accumulate on the lower parts or the base of slopes.

cs-Gypsic Horizon A soil horizon with a visible secondary concentration of gypsum, usually more than 5%.

Debris Flow A dense (60–80% solids, by weight), viscous and rapid flow consisting of coarse particles embedded in fine material. It usually begins on unvegetated talus or colluvial slopes during extremely heavy precipitation. The deposits are unstratified, poorly sorted with coarse particles matrix supported in elongated, lobate forms. Commonly coarse particles armour the surface and form low ridges (levees) bordering the flow.

Debris Flow Fan see: Fan — Debris Flow.

Desert Pavement Desert pavement is a type of surficial cover composed of $\geq 40\%$ gravel, overlying a fine earth (silt,

fine sand, clay) horizon. The gravel is usually mechanically shattered and flat lying.

Divide A belt of separation between drainage systems: the summit of an interfluve.

Dolomite A carbonate sedimentary rock of which more than 50% consists of the mineral dolomite, or a variety of limestone or marble rich in magnesium carbonate.

Dune Mound or ridge of wind blown (or eolian) unconsolidated sand.

Sand dune — An eolian dune and a landform element built of sand size mineral particles.

Stabilised dune — A non-active dune stabilised by vegetation and penetrating airborne dust and salts.

Climbing dune — A dune climbing on a hillslope.

Dust — Desert Dust The material in surficial deposits (including soils) and in the atmosphere composed of particles smaller than 0.0625mm . It consists mostly of silt size particles (0.002 – 0.0625mm in diameter) with lesser amounts of clay ($< 0.002\text{mm}$) and may include some very fine sand (0.0625 – 0.125mm). Dust can remain in suspension in the atmosphere for long periods of time and be transported for long distances.

Electrical Conductivity (in soils)

Electrical conductivity is a measure for the concentration of soluble salts in soils. Electrical conductivity is reciprocal of electrical resistivity. The dimensions are $1/\text{ohm cm}$ or mho per cm . The conventionally used units for soil solution or extract are millimho/cm . The standard temperature for reporting electrical conductivity measurements is

25°C.

Fan — Alluvial An alluvial fan is a body of stream deposits whose surface approximates a segment of a cone that radiates downslope from the point where the stream leaves a mountainous area. Alluvial fans have greatly diverse sizes, slopes, types of deposits and source-area characteristics. They are most widespread in the dried parts of the world.

Fan — Debris flow An accumulation of debris brought down by a debris flow descending through a steep ravine and debouching in the plain beneath where the detrital material spreads out in the shape of a fan.

Fine Earth The textural separate of the soil which includes sand, silt and clay.

Flint (Chert) A hard, extremely dense or compact, dull to semivitreous microcrystalline or cryptocrystalline sedimentary rock, consisting dominantly of interlocking crystals of quartz. It may contain amorphous silica, and impurities such as calcite, iron oxide and remains of siliceous and other organisms.

Flood Plain A geomorphic feature formed by stream/river, it represents the area in which the stream/river flows, erodes and deposits in time of flood. A flood plain is composed of channel and overbank deposits.

Granite A term loosely applied to any light colored coarse grained plutonic rock containing quartz as an essential component, along with feldspar and mafic minerals.

Gravel Sediment or soil particles coarser than 2mm in diameter. Subdivision of gravel: granule - 2-4mm; pebble - 4-64mm; cobble - 64-256mm; boulder - >256mm.

Grus Angular fragments of crystal grain size produced locally by weathering of coarse crystalline rocks, frequently granite.

Hammada A shallow soil developed in situ, usually on hard bedrock on gently sloping terrains, covered by angular rock fragment. The profile includes ABR, ACR, or ABCR horizons (often gypsic or saline).

Hillslope The inclined surface of a hill, mountain plateau, plain or any part of the surface of the earth. Slope is also the angle at which such a surface deviates from the horizontal.

Holocene (Recent) An epoch of the Quaternary (q.v.) period, from the end of the Pleistocene (q.v.), approximately 10,000 years ago, to the present time.

Igneous Rocks A rock that solidified from molten or partly molten material, i.e. from magma.

Limestone A sedimentary rock consisting chiefly (more than 50%) of calcium carbonate, primarily in the form of the mineral calcite, and or without magnesium carbonate.

Lithosol A shallow soil with no well developed AC, ACR, C or CR horizons. Usually formed on soft, friable bedrock, often gravelly and saline.

Loam Soil material or deposit which contains 7-27% clay, 28-50% silt, <52% sand (see figure 1C in chapter C.1).

Loess Material transported and deposited by wind and consisting of predominantly silt with some very fine sand and clay particles.

Loessial Serozem Soil A soil developed of loess parent material. Very light brown or yellowish brown in color, usually sandy loam or loam in texture. Contains carbonate nodules and at depth

gypsum and salts.

Loessial Soil A soil developed from loess parent material. In many cases it forms on alluvial loess, derived from primary eolian deposits. The texture is loam, silty loam or fine sandy loam.

Marl An old term loosely applied to a variety materials, most of which occur as loose, earthy deposits consisting chiefly of an intimate mixture of clay and calcium carbonate, formed under marine or freshwater conditions. 35-65% clay; 65-35% carbonate.

Metamorphic Rocks Any rock derived from pre-existing rocks by mineralogical, chemical and/or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress and chemical environment, generally at depth in the Earth's crust.

Paleosol A soil which have formed in landscapes of the past (see also buried soil/horison).

Plain A region of general uniform slope, comparatively level of considerable extent, and not broken by marked elevations & depressions: It maybe an extensive valley floor or a plateau summit. A plain is here defined as an extensive area having relief $\leq 20m$ and gradients of $<10^\circ$.

Plateau A relatively elevated area of comparatively flat land which is commonly limited on at least one side by an abrupt descent to lower land.

Playa An ephemerally flooded usually barren area on a basin floor that is veneered with fine textured sediments and/or salts. Acts as a temporary or the final sink for drainage water.

Pleistocene An epoch of the Quaternary (q.v.), between the Pliocene of the Tertiary (q.v.) and before the Holocene

(q.v.). It began approximately 1.8 million years ago and lasted until the Holocene came 10,000 years ago.

Quaternary The second period of the Cenozoic era, following the Tertiary. It began approximately 1.8 million years ago and extends to the present. It consists of the Pleistocene (q.v.) and the Holocene (q.v.) periods.

Regosol A deep soil with AC or C horizons, formed from unconsolidated parent material, usually on hillslopes.

R Horizon Continuous, unweathered sediment or bedrock.

Reg Soil A soil with ABC, AC or ABR horizons. Veneered by desert pavement and containing at shallow depth gypsic, salic or calcic horizons. It develops from coarse desert alluvium or colluvium, under an arid to extremely arid climate.

Riser A steeply sloping surface of one of a series of natural step-like landforms, as those of successive stream terraces.

Sabkha A term used on the Arabian Peninsula for a salt flat or low salt encrusted plain restricted to a coastal area, as along the Persian Gulf.

Saddle A low point on a ridge or crest line, generally a divid between the heads of streams flowing in opposite directions.

Sand Soil or sediment particles between 2 and 0.0625mm in diameter. Fine sand $<0.250mm$.

Sandstone A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Sandy Regosol A deep soil with AC or C horizons formed from unconsolidated sand. A horizon is light in color and contains small amount of organic material.

Sandy Soil Sandy soil is a soil which includes sand as a major textural component. Such soil is rather diversified according to the pedogenic processes involved.

sa — Salic Horizon A soil horizon with a visible secondary concentration of soluble salts (frequently chlorides), usually containing more than 2% of salts.

Serozem Soil A soil with ABC or ABB_b horizons, usually light in color. Contains at shallow depth a calcic and/or gypsic horizons.

Shale A fine grained sedimentary rock, formed by the consolidation of clay, silt or mud. It is characterized by finely laminated structure, which imparts a fissility approximately parallel to the bedding. It normally contains at least 50% silt with 35% "clay or fine mica fraction" and 15% chemical or authigenic materials. It is generally soft but sufficiently indurated.

Sieve Deposit Coarse grained lobate masses on an alluvial fan and talus whose material is sufficiently coarse and permeable to permit complete infiltration of water and dust.

Silt A soil or sediment separate consisting of particles between 0.0025 and 0.002mm in (equivalent) diameter. Fine silt - <0.016mm.

Soil Horizon A layer of soil differing from adjacent genetically related layers in various properties (physical, chemical, biological, structure, texture, color).

Soil Profile A soil profile consists of the vertical arrangement of all the soil horizons (q.v.) down to the parent material.

Soil (Deposit) Texture see: Texture of Soil, Deposit.

Solonchak A soil containing high quantities of salts especially in the upper horizons. Develops in playas and sabkhas where saline groundwater level is shallow.

Talus Talus is here defined as a debris mantle on a hillslope or at its foot, formed by rockfall, slope wash, debris flow or creep. It assumes different/various forms: an apron at the foot of a cliff; a cone at the mouth of a gully or a small ravine. The types of talus slopes in the present report are: rockfall talus, debris flow (q.v.) talus, paved (by desert pavement, q.v.) talus and sieve deposit (q.v.) talus.

Takyr A fine textured soil developed on a playa surface without a watertable close enough to the surface to permit salt crust to appear. It usually has a slightly to moderately saline subsoil.

Terrace — Alluvial, Rock-cut
An abandoned, inactive, stream channel, flood plain or alluvial fan.

Alluvial Terrace — a stream terrace composed of unconsolidated alluvium.

Rock-cut Terrace — a terrace, usually cut by a stream in bedrock.

Tertiary The first period of the Cenozoic era, between the Mesozoic and the Quaternary; covered the span of time between 6.5 and 1.8 million years ago. It is subdivided into five epochs: the Paleocene, Eocene, Oligocene, Miocene and Pliocene.

Texture of soil or deposit A measure of the size of the particles components and the particle size distribution (see figure C.1.1.c in chapter C.1).

Tread The flat or gently sloping surface of one of a series of natural step-like landforms, as those of successive stream terraces.

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APPENDIX 4 DESERT SOILS AND SURFICIAL DEPOSITS — CLASSIFICATION AND DESCRIPTION.

In order to be able to estimate or predict the properties of desert soils or deposits in areas which are inaccessible, and to use available tools such as maps, airphotos, and climatic data, it is necessary to resort to a classification based on gross landscape features. A soil classification founded on parent material, landform and climate is largely genetic in nature. Such a genetic soil classification was chosen for the present report. It has been in use in Israel for the last three decades. This soil classification includes the following soil orders and soil types (only the material pertaining to desert terrains is presented here):

1. Climatogenic soils: Serosem soils, Reg soils.
2. Lithogenic soils: Hammada soils, Lithosols, Regosols.
3. Fluviogenic and eolian soils: coarse desert alluvium, alluvial sand, eolian sand, loess, loessial soils.
4. Hydrogenic soils: Takyr soils, Solonchak soils.

These are the soil types frequently encountered in hot-desert terrains. They are typical to the Negev, Sinai and similar Mid-Eastern deserts.

The following is a brief characterisation of the more widespread soil types (for additional information see a Glossary in Appendix 3):

Loessial Soils (aridic)

These are relatively thick (40-200 cm) soils, usually of loam, silt-loam or silt-clay-loam composition, developed on primary eolian or reworked loess. They are usually found in the semi-arid to moderately arid fringes of Mid-Eastern and other deserts, or areas which were under such climatic conditions in the past. Buried or exposed paleosols in loessial sections are occasionally more clayey in nature. Aridic loessial soils often contain pedogenic CaCO_3 in nodules and may contain low concentrations of gypsum and/or salts. The soil is usually covered by a thin (1-3 mm) loess crust, usually denser and more cohesive than the underlying A horizon. The typical landscape of loessial terrains is flat, undulating or badland, with relief usually $\leq 20\text{m}$ (Plate 9A). The natural vegetation is a grass-steppe type. Under desert conditions shallow and saline gypsic Serosem soils develop, often containing some gravel.

Takyr Solis

Takyr soils are relatively thick (40-180 cm), of clay-loam or silt-clay-loam composition, and develop at the center of playas. These soils carry low to moderate amounts of gypsum and salts. The average thickness of the major soil horizons is: A - 7 cm, B - 18 cm, C - 50 cm. The soil develops on fine grained fluvial and eolian sediments deposited at the center of playas. It is usually gravel-free. The terrain is flat and is occasionally inundated by flood water. The soil may remain moist for several months a year. Usually there is a thin loess crust overlying the A horizon and the surface is poor in vegetation or sterile.

Solonchak Solis

Solonchaks soils are highly saline playa and sabkha soils. Usually they have poor or no pedogenic structure, since their properties are determined by both deposition of fluvial and eolian sediments and precipitation of various salts by shallow ground water and inundating

flood water. At the surface there are crusts rich in salts and gypsum. Highly concentrated salt and gypsum layers are found at depth. Sometimes the soil is composed of saline silt and/or clay, but in other cases the soil is coarse textured with an abundance of fine gravel and/or sand. Soil thickness varies from several tens of cm to more than a meter. The relief is flat with some undulations, usually less than 100 cm high. Moisture is usually found close to or at the surface.

Reg Soils

Reg soils are gravelly soils developed on surfaces composed of coarse alluvium, i.e. alluvial fans and alluvial terraces. Their thickness ranges between 30-40 cm in Holocene Reg soils to more than 100 cm in Reg soils on older (Pleistocene) alluvial surfaces. The typical soil profile consists of a surficial gravelly desert pavement, a vesicular horizon underlying it (0.5-7 cm thick), a gravel-free or gravel-poor B horizon (≤ 25 cm) and a gravelly C horizon (usually ≤ 35 cm). There are certain cases in which the B and C horizons are thicker than indicated above. B and C horizons of old Reg soils contain large amounts of pedogenic gypsum, salts, and in many cases, CaCO_3 . Well developed Reg surfaces are devoid of vegetation. The older the surface the smoother it is. Holocene surfaces retain their gravel bar and swale configuration and roughness (Plate 5B), whereas surfaces older than 50-70,000 years are veneered by a complete cover of mechanically weathered angular gravel of ≤ 10 cm in size, to form a smooth desert pavement (Plates 11A,B; 14A,B). Under such a pavement there is usually a gravel-free horizon composed primarily of dust, gypsum and salts.

Hammada Soils

Hammada soils are gravelly soils developed *in-situ* on bedrock, on flat or gently sloping terrains. The gravel is usually mixed with a fine earth fraction composed mainly of dust, from an airborne source; some fine material is derived by weathering of the local bedrock. The surficial appearance and the soil profiles are very diversified:

1. In terrains built of hard brittle bedrock there are usually blocks of exposed bedrock and pockets of soil in-between (Plate 14D). The soils range from gravel and fines with poorly defined horizons, to pockets of loess in shallow depressions.
2. On hard bedrock one may find old Hammada soils that resemble old Reg soils in most respects: a desert pavement of varying degree of evolution at the surface, a vesicular A_v horizon underlying the pavement gravel, a B horizon of varying degree of dust accretion (sometimes gravel-free) and a highly gravelly C horizon merging with the bedrock. Plate 11A illustrates a very well developed Hammada soil on a limestone plateau.
3. In terrains built of hard sandstone, one often finds sandstone gravel overlying sand or sandy loam as a typical Hammada soil (Plate 14 C).

Hammada soils are usually gypsic, saline or calcic.

Lithosols

Lithosols are shallow stony soils without very distinct horizons, on weathered or slightly weathered bedrock and usually they are saline. They are, then, similar in general appearance to some Hammada soils. However, the term lithosol usually applies to the soils that are found on hillslopes, generally over soft bedrock such as chalk and marl. In these cases they are light in color. They are darker where they are developed on hard rocks, such as limestone.

Serosem Soils

Serosem soils are aridic soils (usually of grey, grey brown color) that have calcic, gypsic and/or saline horizons at shallow depths. Excluded are several soils which may have some similar characteristics, such as Reg and Hammada soils. Under the Serosem soil category one may find loessial Serosems, stony Serosems, and calcic Serosems. In all these soils the amounts of dust are high, often several tens of percents.

Sandy Soils

Sandy soils are soils which include sand as the major textural component. Such soils are rather diversified, according to the pedogenic processes involved. Hence, one may define sandy Solonchak soils, sandy Regosols, sandy loessial soils, calcic alluvial sands and others. The dust sized fraction in these soils may reach 10-30%.

Regosols

Regosols are poorly developed soils derived from unconsolidated parent materials (gravel, sand and loess). They are rather deep and are typical to hillslopes or badlands. In deserts there are several types of Regosols: gravelly Regosols, on sieve deposits and other unconsolidated gravelly slopes; sandy Regosols, in sandy terrains; and loessial Regosols on hillslopes in loessial terrains.

Alluvial Soils

Alluvial soils are usually soils that are fluviially derived from some other areas than where they have originally formed. Such soils are accumulations of soil material which has been eroded elsewhere. Within this category one also finds soils that have developed out of alluvial deposits: the structure or stratification of the alluvium is clearly visible in them, in spite of pedogenic horisonation.

APPENDIX 5 SOME GENERAL REMARKS ON THE COMPOSITION, AMOUNTS AND VARIABILITY OF DUST

Note: The Appendix emphasises results and conclusions of Parts C and D in the accompanying report. See these parts for additional conclusions.

The Composition of Dust

The composition of the dust fraction in desert soils and deposits is related to several sources, such as parent material, the composition of allochthonous — mostly airborne — dust and the nature of the precipitated salts. The composition of the airborne dust is largely reflected in the dust fraction of most desert soils and deposits. Generally, it is composed of 50% of medium to coarse silt. Minor amounts of clay and fine sand are always present. However, addition of various size-fractions or differentiation by pedogenic processes may significantly change the original size distribution according to location, topography, climate and age (see chapter E.1 in the report). Especially important is the contribution of sand from eolian and fluvial sources. Soils in areas close to actively contributing sandy terrains are usually sandy to sandy-loam in texture, whereas the texture of soils several tens of km or more from such areas are generally silty-loam to silty-clay (see chapter C.1 in the report). The soils and deposits which are largely derived from distant eolian sources are usually of the finest texture.

Figure C.1.16 expresses the dust content in the various desert soils and deposits in the Negev and the Sinai. A summary based on the data presented in chapter C.1 in the report, table 2 and fig. C.1.16 emphasises the following points concerning the texture of the various soils:

1. Loessial soils.

Young loessial soils are usually silt-loam in nature whereas well developed loessial soils have a texture of silty-clay and silty-clay-loam. These soils are usually devoid of gravel and coarse sand. Loessial Serosems are composed mostly of silt and clay but their particle size distribution varies greatly. The amount of fines (silt+clay) in loessial soils usually exceeds 50% and often reaches 90%. The ratio between clay and silt usually ranges between 0.4 and 0.8. Generally, these soils are similar in texture to settling atmospheric dust.

2. Takyr soils

Young Takyr soils are silt-loam in texture, whereas well developed Takyr soils are usually silty-clay and silty-clay-loam. The soil is composed 80-100% of dust, including 40-60% clay. The clay/silt ratio is usually 0.6-2. As with loessial soils, they are similar in texture to settling atmospheric dust.

3. Solonchak soils

These soils — very poorly developed — reflect the parent material in which they are formed — fluvially derived playa and sabkha deposits. In the southern Arava Valley and along the Gulf of Elat coast they are composed of sand, loamy-sand and sandy-loam; 30-70% sand, 10-20% silt and 1-10% clay. The clay/silt ratio is usually 0.6-1. The amount of gravel is usually very low — <5%.

4. Reg soils

These are silt-loam to clay-loam gravelly soils. In young — Holocene — Reg soils the fine earth is composed mostly (75–90%) of fractions coarser than 0.016mm; The dust fractions is usually 15–40%. Older Reg soils, in areas where there is no appreciable contribution of eolian sand, are rather fine textured: silt — 30–60% and clay — 11–25%. 60–85% sand in the soil is frequently encountered in areas adjacent to sandy terrains. The ratio of clay/silt is usually 0–0.4.

5. Hammada soils

These are silt-loam to sandy-loam gravelly soils. The ratio between coarse silt and fine silt+clay decreases with depth. Dust content in the fine earth is 40–60% and the clay/silt ratio ranges between 0.1–0.6.

6. Lithosols and Serozem soils

Both soil types are very diversified in nature. Dust content in the fine earth is usually 60–80%; most of the remainder is fine sand.

No good correlation was found between the content of silt and clay (chapter C.1 in the report). The most variable clay/silt ratios in different dust storms and rainfall events, as well as the high variability in wetting events and the properties of the parent material are the main causes for such a situation.

The composition and content of salts varies in the different soils. They are calcic in the moderately arid and semi-arid environments and gypsic-salic in the desert terrains. Following is a brief summary of the composition and content of salts in the soils of the Negev and the Sinai (further details and analysis are presented in chapter C.3 in the report and table 2):

1. The least saline are the loessial soils — <0.1–0.7% gypsum. The salts are usually concentrated at depth <30 cm.

2. Takyr soils are saline — 0.3–2% salts and 6–10% gypsum. In basins which are not completely closed the soils are definitely less saline — 0.1–0.3% salts and gypsum.

3. Solonchak soils are highly saline, especially in the inner playa zones; 2–10% gypsum and 0.5–8% salts are frequently encountered, but higher degree of salinity values were observed in many instances.

4. Reg soils are also saline. In Holocene Reg soils there is $\leq 10\%$ gypsum and $\leq 2\%$ salts. The higher values are encountered in the C horizon. In older Reg soils there is a high concentration of gypsum — $\leq 20\%$. Salt content is usually $\leq 2\%$, but often there is a petrosalic horizon at depth of 0.80–1.5 m below the surface. Hammada soils are similar in salinity to Reg soils.

5. Lithosols and Serozem soils are usually saline — 0.1–15% gypsum and 0.1–1% salts.

6. The gypsum/salts ratio is usually the highest in Reg soils — ≤ 10 . In Takyr and Solonchack soils the ratio ranges between 1:1 and 4:1. There is some leaching and wash of salts in gravelly soils whereas most of the gypsum is precipitated and is not leached away.

There is no correlation between the amounts of gypsum and other salts or between salinity and dust content. The evolution of soils under extremely variable conditions is a major reason for this situation (see chapter C.3 in the report).

The mineralogical composition of the particulate non-saline components of the dust fraction is determined by the petrographic composition of the parent materials in the source areas. Much of the dust is of mixed sources and has undergone several or many cycles of weathering, mobilisation, transport and deposition. Hence, in many areas there is only a partial effect of the composition of the local bedrock on the composition of dust. Most of the silt in the Negev and the Sinai is composed of quartz, calcite, feldspar and dolomite. The clay fraction is dominated by montmorillonite, with secondary amounts of kaolinite, illite and quartz (see chapter C.2 in the report). Similar composition prevails over much of the Middle East — a region largely effected by Saharan dust (see part B in the report).

Only limited exposures show a definite compositional evidence of past environments, different from the present; for example, fossil kaolinitic Terra Rossa is found in certain areas of the arid central Negev (see chapter E.1 in the report for elaboration).

The Amounts Of Dust In Different Desert Terrains

The environmental factors that determine the amounts and nature of the dust in desert soils and deposits are described in detail in chapter E.1 in the report. Generally they are: 1. The nature and proximity of the source areas; 2. Climate; 3. Location; 4. Topography; 5. Aspect; 6. Surface roughness; 7. Vegetation; 8. Hydraulic characteristics of the material near the surface — parent material. According to the amounts of dust imported into an area, the quantities of settling dust and surficial properties, one may grade the general terrain types and the soils with respect to their dust content, from the richest to the poorest:

1. Loessial terrains — composed mostly of eolian and reworked silt, clay and fine sand. Such terrains are rich in dust due to a combination of their location with respect to the sources of dust, the atmospheric circulation and the climate — moderately arid to semi-arid — that lead to a high rate of dust settlement and a most efficient dust-trapping vegetation. Thick mantles of dust-rich deposits are typical to these terrains.

2. Playa centers — areas where dust-sized materials accumulate through fluvial wash, differential transport and sorting. Takyr soils, which are composed mostly of silt and clay are derived from these deposits; eolian dust is added to the surface especially during periods of episodic ponding or wetting.

3. Gravelly terrains serve as efficient traps for dust due to their high surficial roughness and porosity. Reg soils are soils with variable amounts of dust; the most developed are soils on Pleistocene coarse-alluvial surfaces. These usually include rather thick (5–30cm) gravel free A_v-B horizons. The C horizon is a gravel-rich layer with variable amounts of dust-sized fractions. Old Hammada soils are of similar nature. In certain cases the rate of dust accumulation may be especially high.

4. Stable sandy terrains are good traps for settling dust. Sandy-loam and loam textures develop on such surfaces.

5. Other terrain types, such as hillslopes with Lithosols on them, carry varying amounts of dust.

Table 2 and figures C.1.16 and C.1.17 should be consulted for further information.

The Thickness Of The Dust-Rich Surficial Mantle

Since most of the dust in desert soils and surficial deposits was derived from the atmosphere, and was emplaced by pedogenic processes, there is a general tendency of high dust concentration to be near the surface and a lowering of the dust content with depth. However, there are terrains in which the accumulation of dust is continuous and the thickness of the dust-rich layer is considerable. Such are the cases of loessial terrains and Takyr soils, which may reach thickness of many meters of continuous silt and clay deposits and paleosols. In sand dune terrains there is sometimes a situation in which eolian sand and dust are added in low rates to a stabilised sand surface. The result is usually a thick layer of sandy-loam or loam. In Solonchak soils, being soils of poor pedologic development in playas and sabkhas, there is also a significant element of accumulation. Under the rather shallow soils that are often encountered, similar such paleosols may be buried. The thickness data that are presented in column 4-5 of table 2 for the above mentioned soils represent only the characteristic soil profile exposed at the surface in the Negev and the Sinai. Buried deposits and paleosols of similar nature should be considered.

Soils and deposits of non-cumulic nature present thickness according to their environmental conditions, such as climate — past and present, parent material, location and topography. As a general rule, the more arid the environment, the more shallow is the soil. In sites under extremely arid climates and/or of flat topography or in the upper parts of hillslopes, there is a low concentration of water and the penetration of dust and salts is rather shallow. Holocene Reg soils and young Hammada soils in the Negev and the Sinai are rather shallow — $\leq 50\text{cm}$ — since they have developed under arid to extremely arid conditions on flat to gently sloping geomorphic surfaces. Old (latest Tertiary to late Pleistocene) gravelly soils on such surfaces are thicker and often attain depths of 140cm. Such soils have been during a part of their evolution under a moderately arid or a slightly wetter climate; the penetration of water, dust and salts has been deeper. Colluvial soils on foot-slopes and toeslopes may also be thicker than the soils on the upper parts of the hillslopes, due to both cumulic nature and the concentration of water from the backslope areas.

On The Variability In The Amounts And Composition Of Dust In Desert Soils

The data in Table 2 present a rather high degree of variability in dust and salts content, composition and thickness. The variability is reflected in four levels: (a) Between soil types. (b) Within a given soil type. (c) Between soil horizons in a given soil type. (d) In any particular soil horizon in a given soil type.

Several topics are of interest in this respect: (a) The thickness of the soil profiles and soil horizons. (b) The proportion between gravel and fine earth materials (sand, silt and clay). (c) The content of dust (silt and clay) within the fine earth. (d) The content, composition and distribu-

tion of salt and gypsum in the soil.

There are many factors which cause the observed degrees of variability in the soil characteristics. These factors are discussed below; they have to be evaluated in conjunction with the data of Table 2 (see elaboration in chapter E.1 in the report):

(a) Local parent material strongly affects soil nature in deserts. Two main soil groups may be defined: (1) Gravelly soils which develop in-situ within weathered hard rocks (Hammada soils) and coarse gravelly deposits (Reg soils). (2) Non-gravelly soils which develop on fine grained deposits (loessial soils, Takyr soils, sandy soils) and fine grained friable rocks (Lithosols). Porosity, permeability and trap efficiency are greatly affected by the texture and structure of the parent material.

(b) Introduction of added — secondary — materials: dust, sand and salts. Addition of autigenic materials into receptive parent materials or a trapping surface is dominant in the evolution of desert soils. Three aspects are significant in causing a high degree of variability in the nature of desert soils: (1) The composition of the introduced materials. One example is the change in the texture of loessial soils — sandy proximal to the provenance of sand (as in the western Negev; g in fig C.1.1A) and loamy, silty or clayey distal (and downwind) to sources of sand (c, d in fig. C.1.1A). (2) Mode and rate of introduction. This is affected by the porosity and permeability of the receptive parent materials and by the method of introduction — wet (by rain or wash) or dry (from windborne dust). The amounts and composition of the introduced materials vary greatly due to changes in the proportional activity of different processes. Widely open textured sieve deposits absorb dust in dry and wet modes to great depths, whereas coarse alluvium with sand is less penetrable. Dust accretion in gravelly environments in deserts is usually subsurface whereas high rates of surficial accumulation are typical to loessial terrains in less arid environments and playa surfaces.

(c) The effects of location and topography. As in parent material, local changes in micro-topography are most frequent in desert terrains. Their effects on the local hydrologic regime and trap efficiency for dust and salts are pronounced. They lead to high variability in dust and salt content and composition. One example of the variation is the dust content and salinity of Reg soils developed on coarse gravelly bars versus finer grained swales. The effects of such initial local features are observed in soils several 10^3 to few 10^5 years of age.

The effects of the aspect are readily observed in some soil types. Among those are the loessial soils, Serossem soils and Lithosols. The variation between differently exposed soils is expressed in soil depth, thickness of soil horizons, particle size distribution and salinity. An example is the thin loessial Serossem soils on south-facing hillslopes versus thicker, less saline loessial soils on north-facing hillslopes in the northern Negev (Plate 2D); the difference depends on both moisture regimes and vegetative cover on the respective hillslopes.

Some systematic variations in soil properties are found on certain landforms; sonation and catenary changes are observed. For example, there is a systematic variation in salinity in gravelly soils on talus slopes from the upper to the lower slope components (table C.3.1 in the report). In playas there is a definite sonation with respect to particle size and salinity from the margins towards the center (Plate 3B, figures C.1.3, C.3.1).

A major factor effecting the variability may be the proximity of a site to a certain source area for introduced materials — sand fields, sandstones, salt flats, etc.

(d) Climatic regimes and their changes. The effect of climate on the soil and deposits in the arid environment is illustrated by the proportion of dust and coarser materials in the soils in the Negev (fig. C.1.1A,B). Loessial soils in the semi-arid northern Negev; Hammada and Reg soils in the arid - extremely arid central and southern Negev. The proportion between dust and gravel generally changes from the less arid northern Negev to the extremely arid southern Negev and eastern Sinai.

Climate is well expressed in soil salinity. An example is the degree of salinity and its distribution in loessial soils of the Negev (fig. C.3.1,2): the more arid the environment, the higher is the salinity and shallower are the saline horizons.

Most Holocene and older soils have developed under an ever-changing climate; they are polygenetic in nature. Paleosols and paleosolic horizons are widespread and are certainly a major source of soil variability. The loessial soils of the northwestern Negev exhibit a sequence of paleosols in their cumulative section. Fig. C.1.15 illustrates the effects of fluctuating climate while loess was accumulating. The different climatic regimes are reflected by the change in soil texture as well as by the CaCO_3 content.

Most Reg soils on Pleistocene alluvial surfaces are relict paleosols, developed under fluctuating climatic regimes. Many of these soils have undergone environmental changes which include climates wetter than at present. The effects of these wetter regimes is expressed in both the thickness of the soil profiles (<1.4 m) and the relative abundance of fines.

(e) Age — the effect of time. The rate of evolution of some soil properties changes and usually decreases with time. Among the properties here examined are relative amounts of dust and salts in the fine earth fractions of the soil. Figures C.1.5,8 in the report and C.3.6 illustrate several general trends for the example of Reg soils: (1) There is a general decrease in the percent of dust after several 10^3 years. (2) There is a very high variability in the content of dust in soil on any given pedomorph surface. (3) There is a general increase in the rate after several 10^3 years. (4) There is a very high variability in the content of salts in the soils on any pedomorph surface.

APPENDIX 8 GROUND COVER — TYPES AND OCCURRENCE

Soils and surficial deposits in deserts are often mantled by some crust — a well defined surficial horizon, different in its texture and structure from the underlying material. In many cases, the surficial horizon is more cohesive, durable and erosion-resistant than the underlying horizon. This is more often the case in soils than in other surficial deposits. In other instances, some indurated horizon was introduced at the surface by erosion of overlying softer layer. The surficial crusts vary in their composition, structure, thickness and degree of induration. Still, some major types should be presented:

1. Loess Crusts

Loess crusts are thin crusts (2-3mm), usually of loam-silt-loam texture (Plate 15C). They are widely spread on loessial deposits and between surface rocks in Reg soils on alluvial and talus surfaces. Loess crusts are composed mostly of silt and clay, densely packed and unaggregated. They are formed by two groups of processes: (a) Mechanical dispersion and deposition by raindrops impact and surficial runoff. (b) Chemical dispersion, washing-in and accumulated of clays.

2. Biogenic Crusts

Lichen, algal and mosses often form a surficial layer over fine grained soils and debris. The resulting crusts protect the underlying profile from the impact of raindrops and erosion by runoff and winds. Dust is usually trapped by lichen colonies and mosses and between them. The resulting crusts, composed of dust, plants and precipitated salts are of variable thickness: In the vicinity of Jerico (-100 mm/year of mean precipitation) a ≤ 20 cm thick crust has developed during a period of several thousand years over chalks and marls of the late Pleistocene Lisan Formation. Near Massada, some 50km to the south (-60 mm/year of mean precipitation) the crust is only a few mm thick.

3. Crusts on Playa/Sabkha Surfaces

Surficial layers of playa surfaces are diversified. Three main types are apparent:

(a) Clayey crust. These crust, composed of 40-75% clay appear in playa centers which are covered occasionally by flood water. The coarser fractions are deposited behind, in the playa margins (see Part D in the report). Fine airborne dust is added to the surface while it is wet. In these playas there is no permanent shallow water table and the surface is dry for long periods of time. Salts in large amounts are not added and in fact they are leached by percolating floodwater. The crusts are hard, smooth and devoid of vegetation, overlaying Takyr soils.

(b) Salt Crusts are typical to playas and sabkhas where high groundwater level is discharging water to the surface repeatedly or continuously. The salts precipitated upon evaporation are mostly chlorids, sulphates and some carbonates. Crusts of variable thickness are formed (Plate 3D). The surface is usually rough, composed of small crests and troughs, polygons of various sizes and small solution pits. During long periods of time the soil (Solonchak) is wet and soft at the surface.

(c) Soft puffy surfaces are frequently encountered in playas where rapid capillary rise of water is derived from a very shallow water table. The micro-topography of such surfaces may attain 15 cm (Plate 3C,D). High salt content and rather large particles sizes — sand and silt (very little clay) are typical. The surfaces is wet periodically. Shallow water inundation occurs occasionally; and dissolution of salts and smoothing of the sur-

face take place, only to become rougher again upon drying.

4. Surficial Gravel

Gravel, cobbles, stones, etc., appear on many landforms developed from hard brittle bedrock: stream channels, alluvial fans, alluvial flood plains, rocky plateaus, hillslopes (Plates 5,6,14). Rock blocks of various sizes are exposed by erosion of hillslopes and carried downstream. The size of the gravel is governed by several factors: joint spacing, breakdown and attrition during periods of movement, sorting during periods of transportation and weathering during periods of rest. The general trends are described in Part D and figures D.2a-d in the report. It is during the period of long rest that dust is added to the gravel, through weathering and introduction of airborne materials: Reg soils, Hammada soils and Lithosols are common results of the movement of water, and deposition of dust and salts within the gravelly debris mantle.

5. Desert Pavement

Desert pavement is a gravelly surficial cover of $\geq 40\%$, overlying a fine soil horizon. It is usually composed of coarse fluvial gravel, partly or completely shattered by mechanical weathering. The resulting gravel is often 1-7 cm in median diameter; it is stable in place, lying flat, short axis vertical (plate 5B1; 11A; 14B). Desert pavement is characteristic to gently sloping coarse-alluvial plains that are not fluvially active, Hammadas on rocky flats and talus slopes of medium and gentle gradients. The gravel may be varnished or pitted on the upper side.

Several processes are involved in desert pavement evolution: (a) Mechanical weathering of original gravel; (b) Winnowing and washing away of fine particles ($< 2\text{mm}$) by wind, runoff and percolation; (c) Migration of gravel towards the surface; (d) Downward movement of dust introduced by wind and rain — fine sand, silt, clay. With time, a thin (0.5-6.0 cm) loamy vesicular horizon develops underneath the gravel and between the discrete rocks. In the latter cases it is covered by a thin loess crust. During several tens of thousands of years a gravel-free B horizon may develop under the vesicular layer.

The course of evolution of desert pavement on alluvial surfaces is as follows: (a) At an early stage there is usually a near complete cover (75-95%) of the surface by fluvial gravel and some fines. At this stage there is a gravel-bar and swale topography at the surface. (b) During a later stage there is a slow obliteration of the gravel bars by the mechanical weathering of the surficial gravel, trapping of airborne dust underneath and between the surficial gravel and evolution of Reg soils (Hammada soils may develop in a similar manner). Figure C.1.9 illustrates the change of pavement cover with time on a Holocene sequence of alluvial surfaces. (c) Several 10^5 years elapse until the surface is composed mostly ($>85\%$) of secondary (mechanically weathered) angular gravel and the differences in elevation between bars and swales (being originally 20-60 cm) are completely eliminated. The conditions that determine the rate of this process are the size of the original gravel and surficial features, the ability of water to penetrate the individual rocks and the amount of salts available for the mechanical weathering process. A smooth surface of desert pavement on alluvial surfaces composed originally of small cobbles and pebbles, indicates an age of more than 13,000 years and in most cases more than 30,000 years. (d) After several 10^5 years, when the soil profile is highly plugged with fine silt, clay and salts, there usually occur stripping and erosion of the Reg soil and some chemical crust, composed of gypsum, salts or calcium carbonate may be exposed at the surface.

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