311

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311

THE EFFECT OF SOIL LANDSCAPE AND QUATERNARY GEOLOGY ON THE DISTRIBUTION OF SALINE AND FRESH WATER AQUIFERS IN THE COASTAL PLAIN OF ISRAEL*

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Investigation of soil characteristics and preparation of soil maps is a prerequisite of agricultural planning. The soil maps prepared under such investigations may be used for other purposes, such as road construction and other engineering projects. This article shows how soil maps of the Coastal Plain of Israel can be used in evaluating the groundwater characteristics of the coastal aquifer.

The existence of a close relationship between soil characteristics, distribution and processes induced by environmental factors is known from studies undertaken in many countries (3,13). The Quaternary geology of the Israel Coastal Plain has also been affected by these relationships, since the soil forming processes during this period were similar to those occurring today.

Quaternary geology

The Coastal Plain of Israel is a subsiding region (7,8,14). Quaternary sediments cover Neogene "Sakia" marls and clays (Fig.1). These marls interfinger at the eastern part of the region with coastal deposits of sands and conglomerates. The Quaternary sediments themselves consist mainly of a series of marine sandstone, with some

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SCHEMATIC GEOHYDROLOGICAL CROSS SECTION

(NOT TO SCALE)

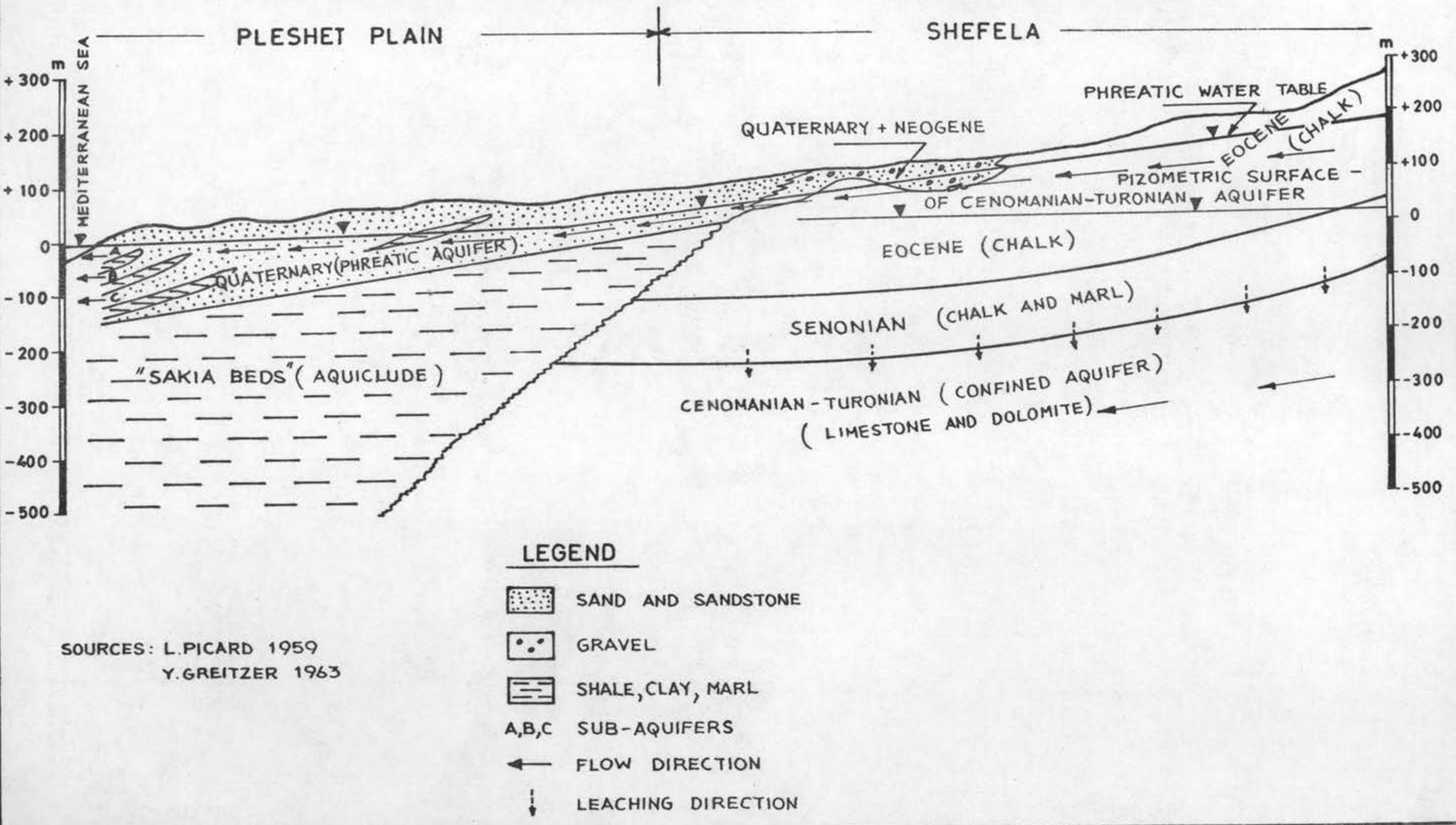


FIG. 1

layers of marls and shales, intercalated and covered by sand, and sandstones which originated from coastal dunes. These terrestrial sands are covered by soils of various thicknesses. Several sedimentary systems of these deposits have been discovered, especially in the western part near the recent coastline. In the east, they diminish till only one dune system is found near the eastern margin of the coastal plain. The distribution of these systems is related to the subsidence of the region--mainly the western part of it, the general worldwide regression of sea coasts, and the fluctuation of sea level during the Pleistocene age. Hence, the eastern dunes are the oldest and are related to early Pleistocene sands while the western dunes are much younger.

The dunes first underwent a stage of stabilization which subsequently gave way to processes of soil formation. Simultaneously with these processes, an aeolian dust, originating from the large desert regions to the south and east of Israel, began to cover the dunes (3, 5). Sedimentation of this aeolian deposit was comparatively fast in the south near the desert, decreasing slowly towards the north. The sediments are not of uniform depth, their thickness being much greater in the east owing to a longer period of sedimentation. Local changes in the thickness of the fine-textured sedimental cover also occur and are attributed to catenary redistribution, and to sedimentation in the floodplains (3, 4, 5). The thickness of these sediments ranges from ten to forty metres in the floodplains and terraces to about ten metres in the south-eastern hilly area, and from one to three metres on the non-eroded upland areas in the south-western and north-eastern parts of the coastal plain. In certain areas, such as in the vicinity of Dorot and Ruhama, most of the fine-textured sedimental cover has been eroded due to recent erosive cycles induced mainly by human activity (3).

Hydrogeology

The coastal aquifer consists mainly of Quaternary sands and sandstones (7). At the eastern section of the coastal region, these sediments are thin and lie above the groundwater table.

In the area lying south of Ramle, the coastal aquifer is connected to the Neogene aquifer of sandstones and conglomerates (12). Further to the east, a somewhat saline Eocene aquifer is found (Fig.1). North of Ramle, along the margin of the mountain region, in the northern part of the coastal plain, waters of the coastal aquifer mix with fresh groundwater found among the Cenomanian and Turonian rocks.

The groundwater table lies at about zero to three metres above sea level in the western part of the area. Towards the east, the elevation of the groundwater table rises, reaching ten metres or more in the vicinity of the eastern limits of the region. Groundwater replenishment in the coastal region derives mainly from local rainwater and only small amounts of groundwater reach this region from the east (1).

Climate

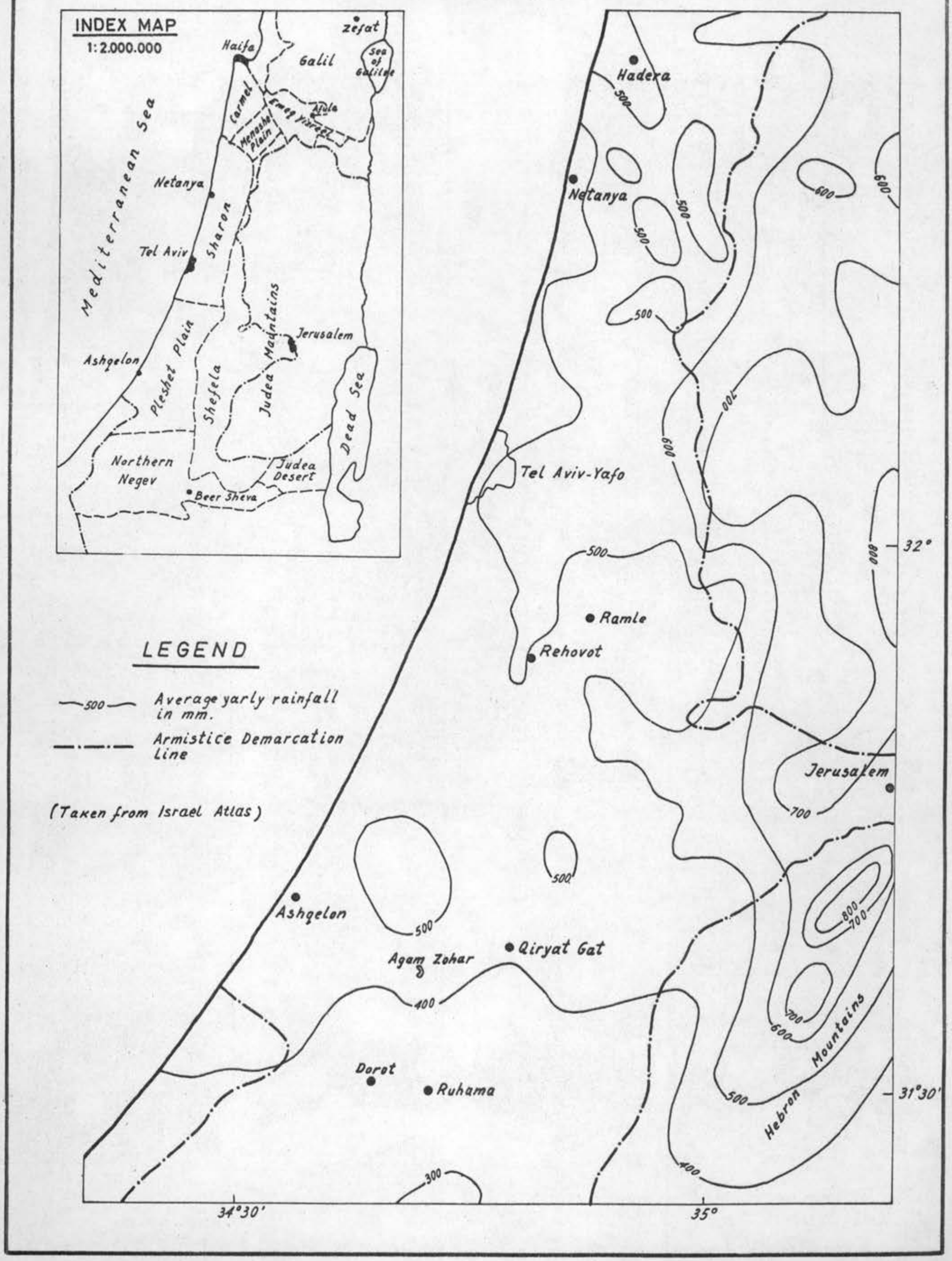
A sub-humid climate (15) with an annual precipitation of 500 to 600 mm (Map 1) characterizes the northern part of the coastal plain. Annual precipitation decreases southward and reaches only 350 to 500 mm in the semi-arid areas of the Pleshet Plain. In the arid northern Negev the precipitation is even less, varying from about 150 to 350 mm per year.

Soil leaching processes

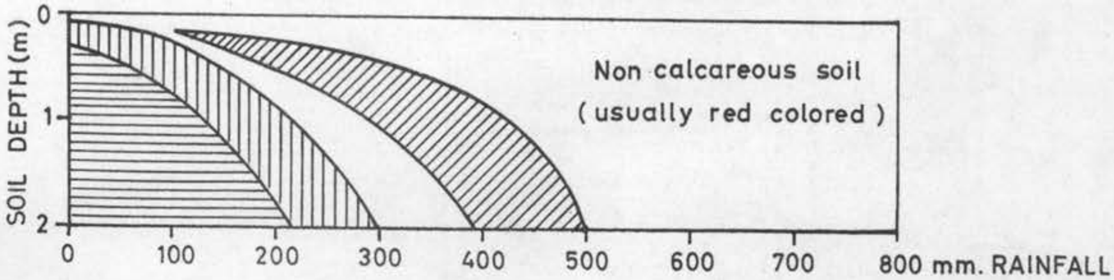
Soil forming processes in Israel include, among others, enrichment in lime and soluble salts due to airborne deposition on the one hand (11, 16, 17), and leaching of these compounds on the other hand. The state of equilibrium reached between these two processes depends

ISRAEL RAINFALL MAP

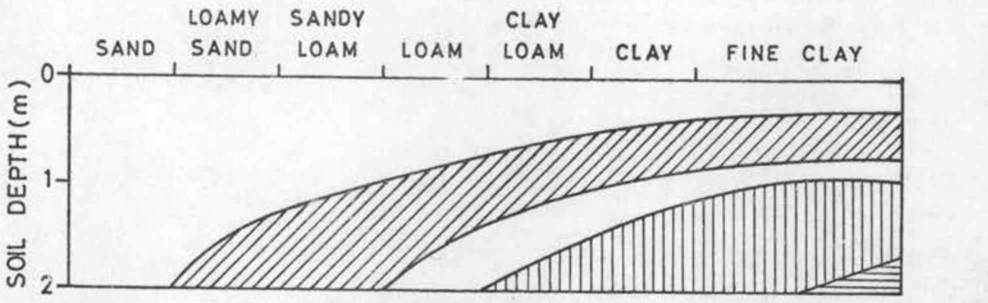
Scale 1:500,000



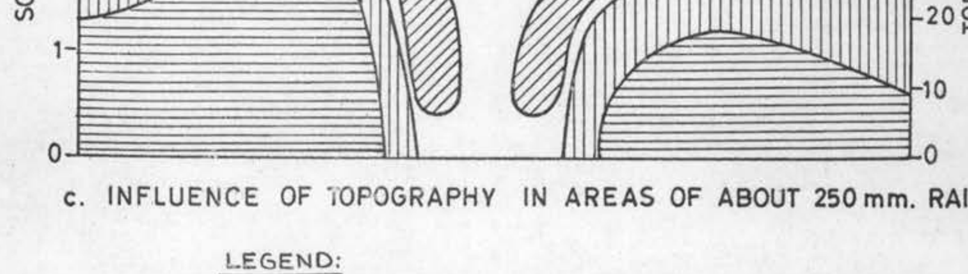
THE EFFECT OF ENVIRONMENTAL FACTORS ON SOIL LEACHING IN ISRAEL



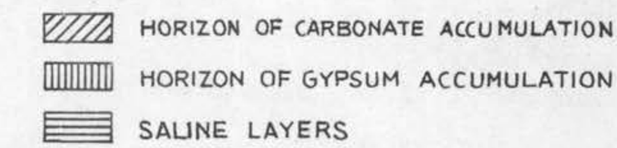
a. INFLUENCE OF CLIMATE ON MEDIUM TEXTURED SOILS



b. INFLUENCE OF TEXTURE IN AREAS OF ABOUT 350 mm. RAINFALL



c. INFLUENCE OF TOPOGRAPHY IN AREAS OF ABOUT 250 mm. RAINFALL



on the depth and amount of water percolation (3, 13). Hence, leaching is restricted to arid regions, fine-textured soils and undulating or hilly upland areas. In these places, the soluble compounds may be deposited in soil layers of various depths, forming horizons of lime (ca), gypsum (cs) and salt (sa) accumulation (Fig.2). Leaching processes are accelerated, on the other hand, in humid regions, in coarse-textured soils, in shallow soils covering highly permeable rocks and in well-drained floodplains and depressions. This phenomenon is expressed even in desert regions where the gravelly and sandy sediments of dry river-beds are free from soluble salts.

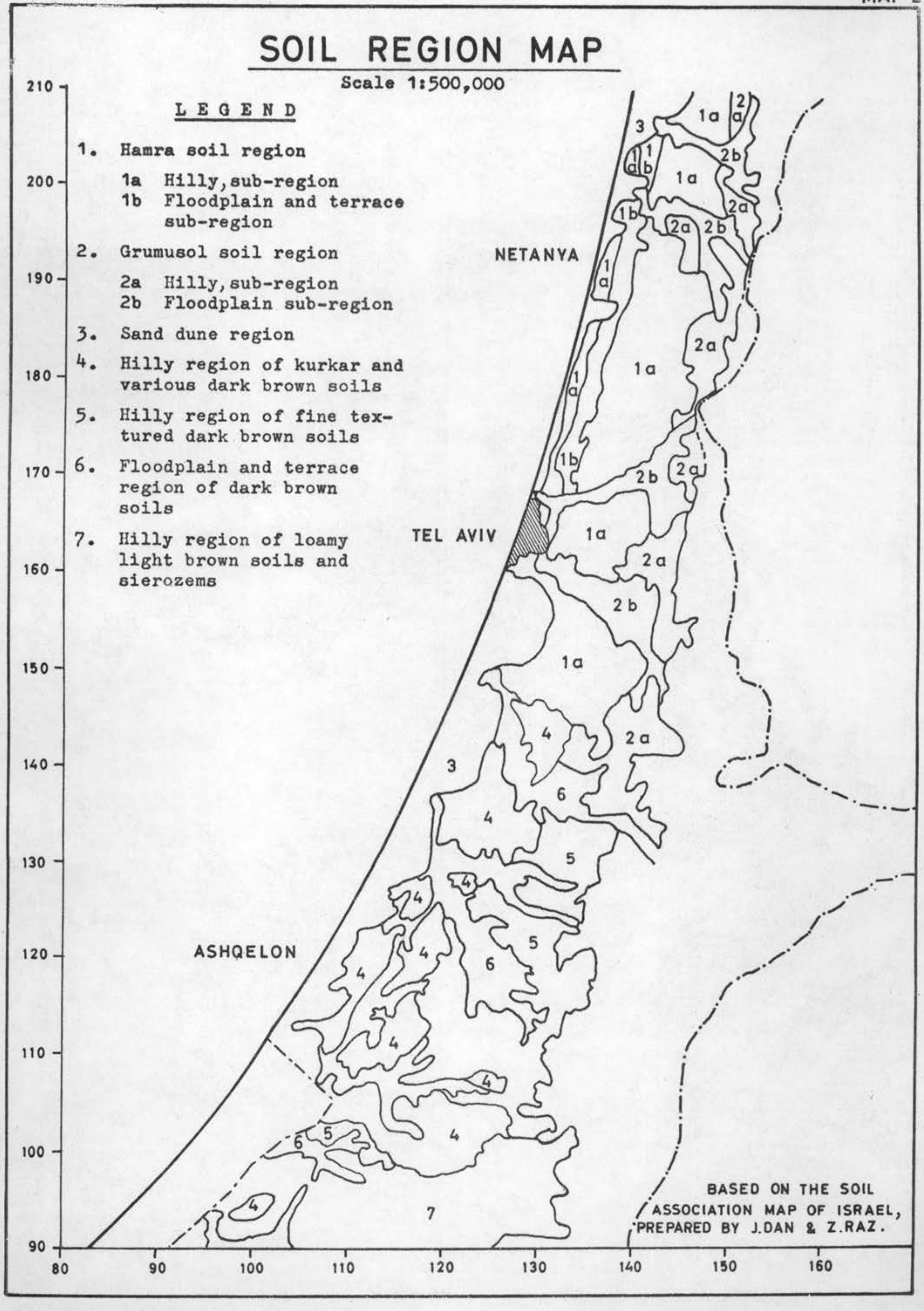
As a result of the above-mentioned processes it is possible to delineate the following soil regions (Map 2).

Soil Region 1

A region of leached, coarse and medium-textured Hamra soils in the Sharon and northern Pleshet Plain; the soils in this region are, as a rule, non-calcareous. The region may be subdivided into a hilly sub-region where most of the soils are highly permeable (Soil Region 1a), and a floodplain and terrace sub-region in which clay pans and impervious fine-textured soils are quite widespread (Soil Region 1b).

Soil Region 2

A region of fine-textured soils, mainly grumusols, in the eastern Sharon. Similar areas are also found in the valley of Esdraelon and other valleys in northern Israel. The carbonates are usually leached to some extent, especially from the upper soil layers, but some of the lime may be reprecipitated at a depth of about one to two metres forming a typical ca horizon. This region may also be subdivided into the hilly areas where soils show well-developed profiles (Soil Region 2a), and the floodplains where the soils may still resemble the feature of fine alluvial sediments (Soil Region 2b).


SOIL REGION MAP
Scale 1:500,000
LEGEND
1. Hamra soil region
1a Hilly, sub-region
1b Floodplain and terrace sub-region
2. Grumusol soil region
2a Hilly, sub-region
2b Floodplain sub-region
3. Sand dune region
4. Hilly region of kurkar and various dark brown soils
5. Hilly region of fine textured dark brown soils
6. Floodplain and terrace region of dark brown soils
7. Hilly region of loamy light brown soils and sierozems
NETANYA
TEL AVIV
ASHQELON
1a
1b
2a
2b
3
4
5
6
7
210
200
190
180
170
160
150
140
130
120
110
100
90
80
90
100
110
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130
140
150
160
BASED ON THE SOIL ASSOCIATION MAP OF ISRAEL, PREPARED BY J.DAN & Z.RAZ.

Soil Region 3

A large dune area in the western Pleshet Plain.

Soil Region 4

A hilly area of exposed Kurkar (calcareous sandstone or aeolinite), together with a mixture of coarse, medium and fine-textured dark brown soils; this area lies in the western part of the Pleshet Plain. A somewhat similar soil distribution is found in the recently eroded areas near Dorot and Ruhama. The soils are usually calcareous throughout and typical ca horizons are found at a depth of about one metre.

Soil Region 5

A hilly region of fine-textured dark brown soils in the eastern part of the Pleshet Plain. Soils are calcareous throughout and a ca horizon is found at a depth of about one metre. These soils cover, as a rule, clay layers of about five to ten metres which are usually somewhat saline.

Soil Region 6

An area of floodplains and low terraces in the Pleshet Plain. The soils are usually similar to those of the last region; however, they may differ somewhat in texture since the silty fraction is usually more abundant. Furthermore, the salinity of the clays which underlie the soils is somewhat lower.

Soil Region 7

A hilly region of loamy light brown soils and sierozems in the northern Negev. The soils are usually loamy in the upper horizon and finer-textured in the deeper layers; they are calcareous throughout. The ca horizon is found already at a depth of about half a metre. Gypsum and other soluble salts may also be found in the deeper soil layers, in particular in the southern part of the region (the sierozem soil region). Generally, the soils cover layers of saline clays, especially in the northern part of the region. The underlying rocks include mainly sandstone, sands or gravel, most of which are also slightly saline. Eventually, the upper layers are eroded, so that soils are formed from the underlying sand or sandstone.

Salinity of the unsaturated subsurface layers

According to data accumulated during recent years* (9, 10), the layers lying beneath the coarse to medium-textured soils of the Sharon and the sand dune in the western Pleshet Plain have a chlorine content of less than 0.01 percent. These values range from 0.01 percent to 0.025 percent in the sandstone layers and reach 0.1 percent in the paleosols and clay layers which lie beneath the medium-textured soils in the western part of the Pleshet Plain.

In the clay layer which underlies the fine-textured soils of the south-eastern part of this region, chlorine content may exceed 0.1 percent. These values are even higher in the layers underlying the loessial soils of the northern Negev.

Groundwater salinity (Map 3)

The salinity of the groundwater in the Hamra region (Soil Region 1) is less than 100 mg/l Cl; in some areas it is as low as 30 mg/l. The low salinity values indicate good direct recharge of the aquifer. Along the floodplains of fine-textured soils which cross this area (Soil Region 2b), the salinity values of the groundwater are usually higher than 100 mg/l Cl and in certain areas reach values of 500 mg/l. In this area, the recharge is probably inhibited due to the fine-textured soil and impervious layers.

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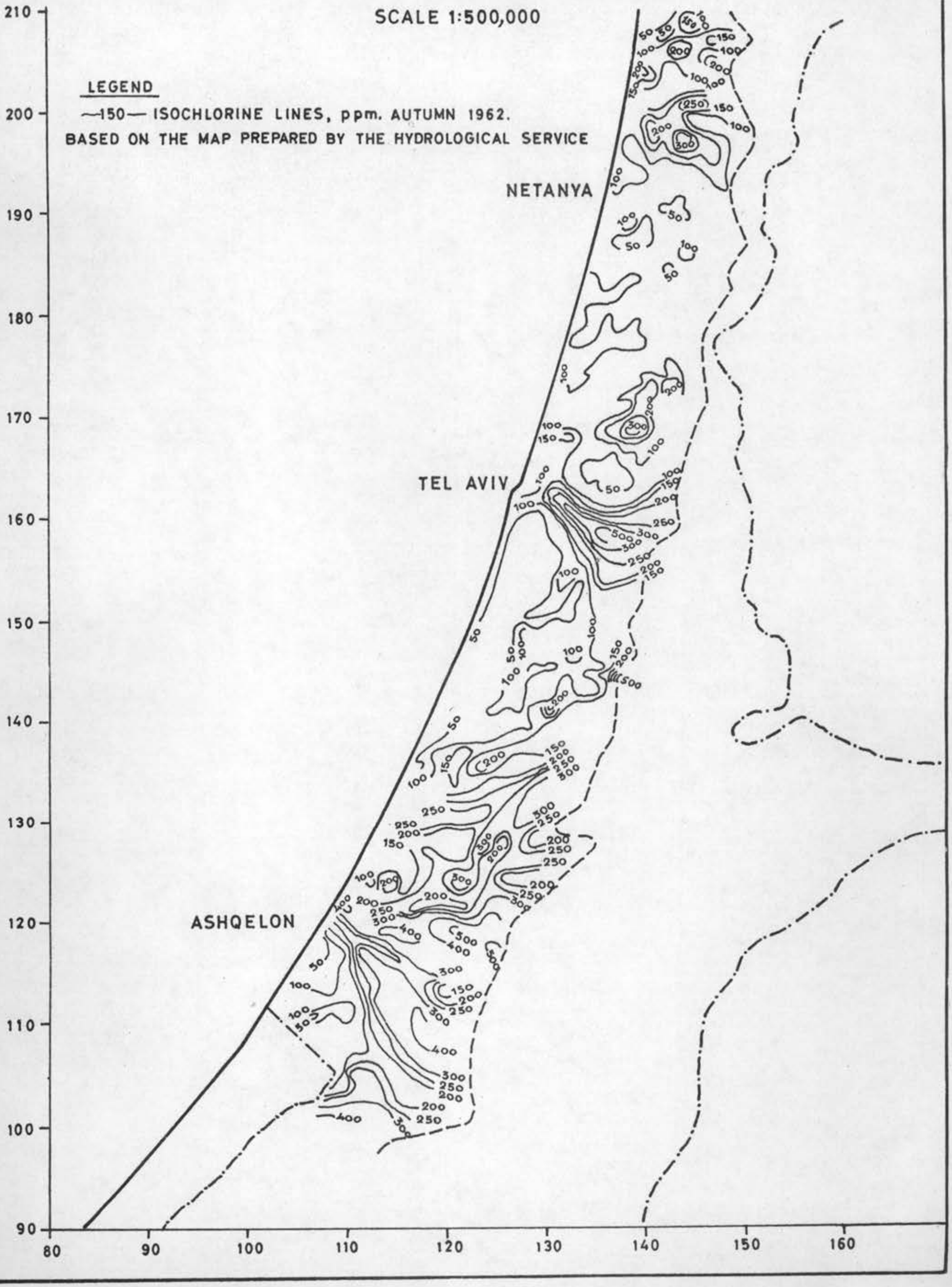
* Mainly unpublished data.
Source: Research and Development Department, Tahal

GROUNDWATER SALINITY IN THE COASTAL AQUIFER



There was no rise in groundwater salinity in Soil Region 1b and 2a, although there seems be only a small recharge in these regions due to the fine-textured soils and impervious layers. Both these regions are narrow and cross the natural gradient and flow line of the groundwater. It seems, therefore, that the groundwater of Soil Region 1b comes mainly from the large Hamra region in the east, while the groundwater found in Soil Region 2a is pumped to a large extent from the Turonian-Cenomanian aquifer.

Groundwater salinity in the Pleshet Plain generally increases towards the south and east; the groundwater beneath the sand dunes is fresh (less than 100 mg/l Cl). In Soil Region 4, the groundwater salinity ranges from 100 to 200 mg/l Cl in the northern part of the area and reaches 300 mg/l in the southern part. In the south-eastern part of the Pleshet Plain, in Soil Region No.5, the groundwater salinity may exceed 500 mg/l Cl. It is possible that in these areas most of the groundwater enters the region from the Eocene aquifer (12), since it seems that very little water penetrates through these undulating fine-textured soils under the prevailing climatic conditions. In the floodplains which cross this region (Soil Region No.6), the groundwater is somewhat less saline, generally only about 200 to 300 mg/l Cl. Some water may reach the aquifer of the floodplains due to the coarser-textured soil, the topographical conditions which are not conducive to much runoff, and to the consequent accumulation of flood water. The occurrence of a comparatively fresh water aquifer in the vicinity of Dorot and Ruhama may be accounted for by the coarse and medium-textured soils found in this area.

In the northern Negev the salinity of groundwater in the coastal aquifer is usually very high as rainfall is too scarce to penetrate the soil (16).

It appears that the salinity of the groundwater in the coastal plain is derived mainly from the rainwater since local rainfall is the main source of groundwater in this area (16, 17). The salinity of rainwater is very low (11, 17); nevertheless, salts contained in rainwater may accumulate in areas where percolation of water through the soil is inhibited or where all rainwater evaporates prior to percolation. The calcium, gypsum and salt accumulation horizons in the soil also result from the same factors, as well as from the leaching processes. Thus, the soil characteristics may serve as an indicator of groundwater replenishment and salinity. However, such a correlation may not exist in areas where the soil regions are narrow and where these regions cross the natural gradient and flow line of the groundwater. Furthermore, the percolation of rainwater in some areas is nil or almost nil owing to conditions of aridity, fine-textured soil, a high runoff coefficient or a combination of these factors. In these cases, the groundwater may originate from a neighbouring region, although some mixing with local water may occur.

The salinity of the groundwater cannot always be determined from a study of local soil-water conditions. This applies, for example, to certain areas near the eastern limits of the coastal plain where the groundwater is pumped from Cenomanian-Turonian aquifers. In these areas, comparatively fresh water is pumped even in the light brown soil region. The source of groundwater in this area is in the Hebron mountains (6); hence, in this case, groundwater salinity is not dependent on local conditions but on the soil-water relationship in these mountains and in the area through which the water flows.

Some salination of groundwater has occurred during recent years (2) due to irrigation practices. This rise in salinity cannot, however, explain the general trends in the quality of the groundwater as the average yearly rise in the western part of the Pleshet Plain does not normally exceed 0.5 to 0.8 mg/l Cl. On the other hand, there has been some improvement of groundwater salinity in the vicinity of Lake Zohar due to percolation of fresh water from this artificial reservoir.

The above correlations have been established on the basis of general soil and groundwater isochloric maps. It would be advisable to undertake a thorough study of the whole geochemical cycle by comparing soil characteristics, water percolation and groundwater salinity and replenishment. Such a study may well lead to the development of a good tool for the prediction of groundwater replenishment and salination in sub-humid and arid regions.

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311

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