QUESTIONS OF THE OIL-CONTAMINATION OF SOIL-WATER AND AGRICULTURAL SOILS IN THE SOUTHERN PART OF THE HUNGARIAN BASIN

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It is known that soil-waters are the waters of the strata immediately adjacent to the surface, which are fed from the precipitation falling on the surface and draining away there, and from other surface waters. It is also known that in the feeding of the soil-waters of the Great Hungarian Plain a significant part is played by the living water-courses on the surface: this includes not only the larger streams and rivers, but also the artificially created canal and channel network. In fact, there is a constant flow interaction connection between the surface water network and the soil layers; this may at times be of decisive importance as regards the direction and rate of flow of the soil-waters, their changes in level, and their chemical composition. In periods when the surface waters flood, the river or canal water generally flows from the bed into the conducting soil layers, while at times of low water the beds of the rivers act on the movement of the soil-waters as depression axes.

It is justified, therefore, to assume that the soil-waters can be contaminated by both oil-industry waste waters, for example, and mineral-oil derivatives originating from the various sources. This can occur not only as a result of periodic concentrated infiltrations in the direct vicinity of the discharge, but also throughout the entire length of open-section sewage-carrying channel networks and river beds with low rates of flow, which thus provide only a slight dilution.

Accordingly, in the interest of being able to assess this hypothetical correlation in the concrete regional characteristics of Southern Hungary, we have collected data for the periodic quality control of the soil-waters of the region. Apart from our own examinations, we have also made use of water-analysis data of the VITUKI, the National Geological Institute and the Water-Control Inspectorate of the Lower Tisza Water Board. These latter were restricted to single examinations in the cases of the individual soil-water wells, and thus were of inestimable value primarily in the regional information.

The results of the examinations are summarized in Table 1, Figs. 2—8 (diagrams showing the change in the water quality), and Fig. 1, a sketch-map of the recording positions.

If it is desired to evaluate the results, it must first of all be stated that oil-contamination could not be detected anywhere in the soil-waters, not even in the case of the soil-water test bore in the vicinity of well no. 168 at Algyő, in spite of the fact that unexpected gushing of a well led to more than 20,000 tons of oil pouring onto the surface of the soil, a proportion of this infiltrating.

Naturally, minor discharges and drippings occur everywhere on the oil-producing sites; these fall to the ground and thence enter the channels too. The danger of such

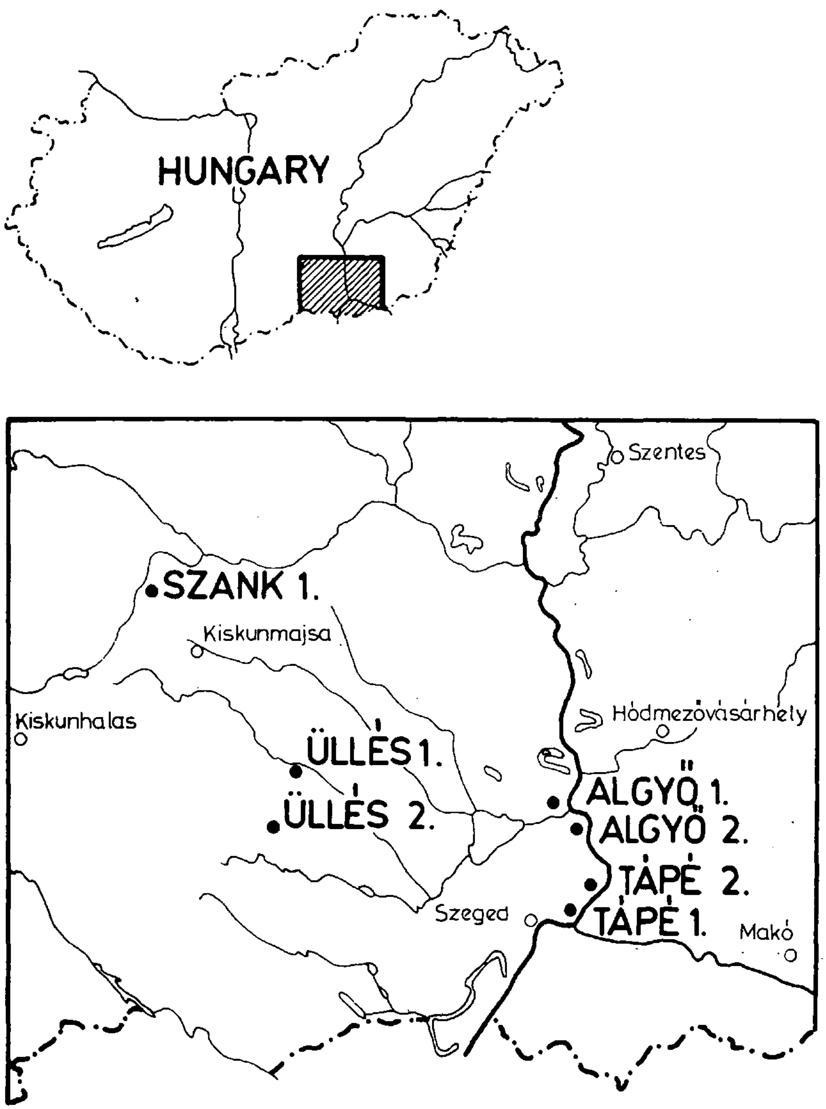


Figure 1. COMPREHENSIVE SKETCH-MAP OF THE SOIL-WATER WELLS ON THE SOUTH HUNGARIAN PLAIN WHICH WERE EXAMINED WITH REGARD TO THE CHANGES IN WATER-COMPOSITION

TABLE 1.

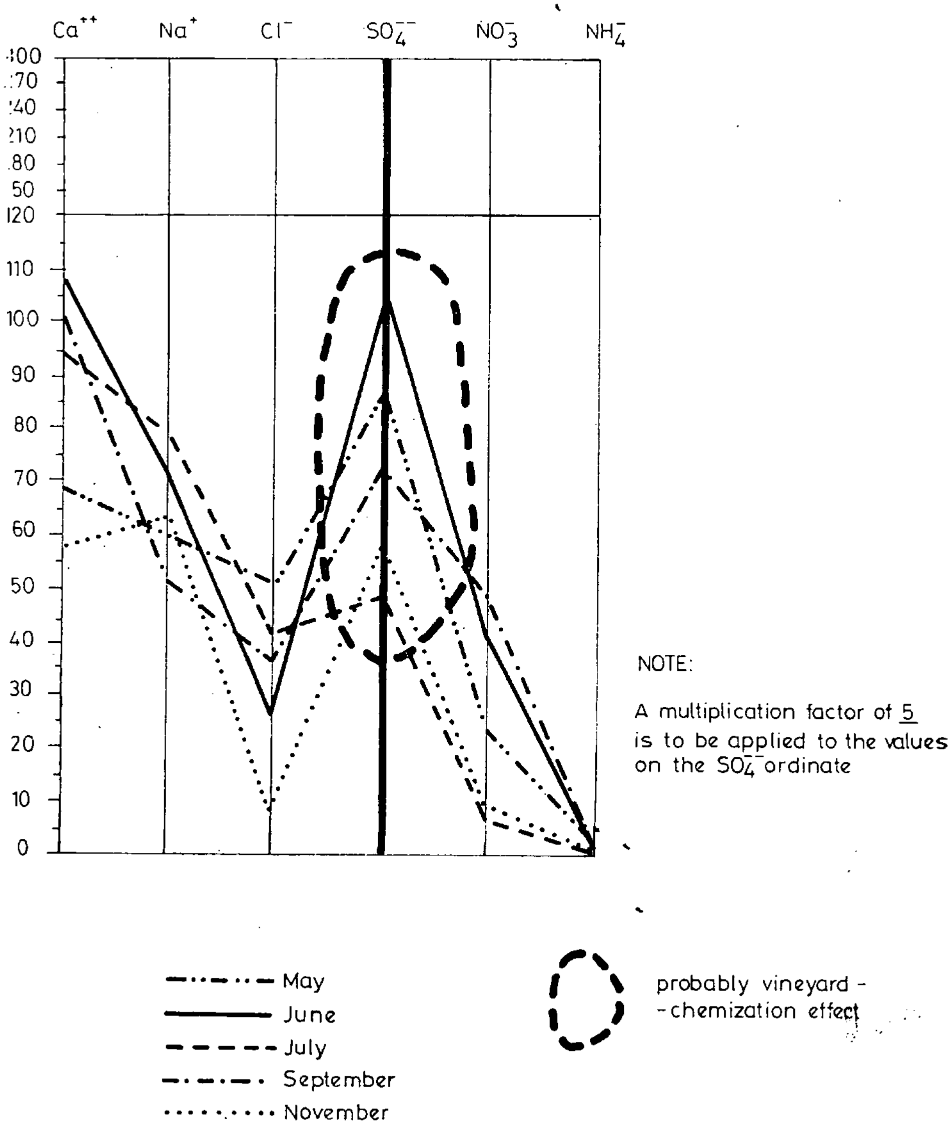
More important constitent characteristics of the chemically-examined soil-water wells of the South Hungarian Plain

(The compilation has been prepared on the basis of the data of the Water-Control Inspectorate of the Lower Tisza Water Board)

Place	Number of wells analyzed	Total hardness			Dissolved salts mg/l			Na as percentage of cations			SO_4 mg/l		
		min.	max.	ave.	min.	max.	ave.	min.	max.	ave.	min.	max.	ave.
Ásotthalom	1	—	—	11,6	—	—	352	—	—	38,4	—	—	35
Battonya	2	32,1	180,3	102,6	1263	7 320	4291	25,6	39,7	32,6	155,6	1294,0	702,3
Balástya	1	—	—	7,7	—	—	1972	—	—	89,6	—	—	26,9
Bordány	1	—	—	15,3	—	—	291	—	—	3,2	—	—	53,0
Csorvás	3	4,1	37,4	19,3	347	1 784	902	36,9	76,3	53,8	44,6	383,6	171,2
Gádoros	17	15,7	51,5	28,0	624	2 459	962	22,2	79,8	28,8	119,5	385,0	191,3
Hódmezővásárhely	24	9,4	140,0	87,0	605	5 418	2764	20,8	67,9	28,7	52,6	1133,0	843,2
Kevermes	4	20,8	47,2	29,9	553	1 162	1044	12,2	57,4	32,0	61,9	351,2	177,7
Kiszombor	1	—	—	46,5	—	—	1574	—	—	27,8	—	—	371,0
Kétegyháza	1	—	—	22,1	—	—	890	—	—	47,8	—	—	17,3
Mezőhegyes	6	26,2	240,8	72,8	933	11 245!	3869	36,6	46,8	42,7	77,6	2810	801,6
Medgyesegyháza	18	14,7	21,2	17,8	461	669	545	10,1	22,9	13,5	19,2	112,2	76,2
Makó	1	—	—	20,2	—	—	1313	—	—	50,0	—	—	203,6
Mórahalom	1	—	—	16,9	—	—	310	—	—	4,5	—	—	17,7
Nagyszénás	7	11,0	61,2	27,4	642	1 340	866	32,0	61,5	50,9	57,2	215,5	109,8
Orosháza	20	9,9	60,4	30,5	552	3 300	2002	23,5	84,8	64,5	19,2	765,0	760,8
Pusztaottlaka	6	7,7	22,7	14,8	344	1 191	782	31,4	84,7	55,8	34,2	121,4	77,5
Pusztamérges	5	22,9	29,5	26,3	495	671	590	5,4	9,5	7,6	43,2	157,5	95,2
Reformátuskovácsháza	2	22,9	59,2	41,0	933	2 846	1699	40,8	53,8	47,3	168,3	662,0	415,1
Szeged	17	19,3	240,0	101,1	620	13 456!	5853	11,7	55,5	33,6	129,9	2840,0	1170,7
Szőreg	2	34,5	162,4	98,5	2044	5 842	3943	29,0	35,7	32,3	165,2	1 880,0	1022,6
Szank	10	13,8	64,9	30,2	300	3 305	1170	6,2	26,3	13,8	61,1	286,0	162,5
Szarvas	1	—	—	38,3	—	—	3916	—	—	48,0	—	—	446,0
Üllés	5	19,3	67,9	44,9	392	2 443	1262	4,9	21,1	13,8	53,0	692,0	293,0

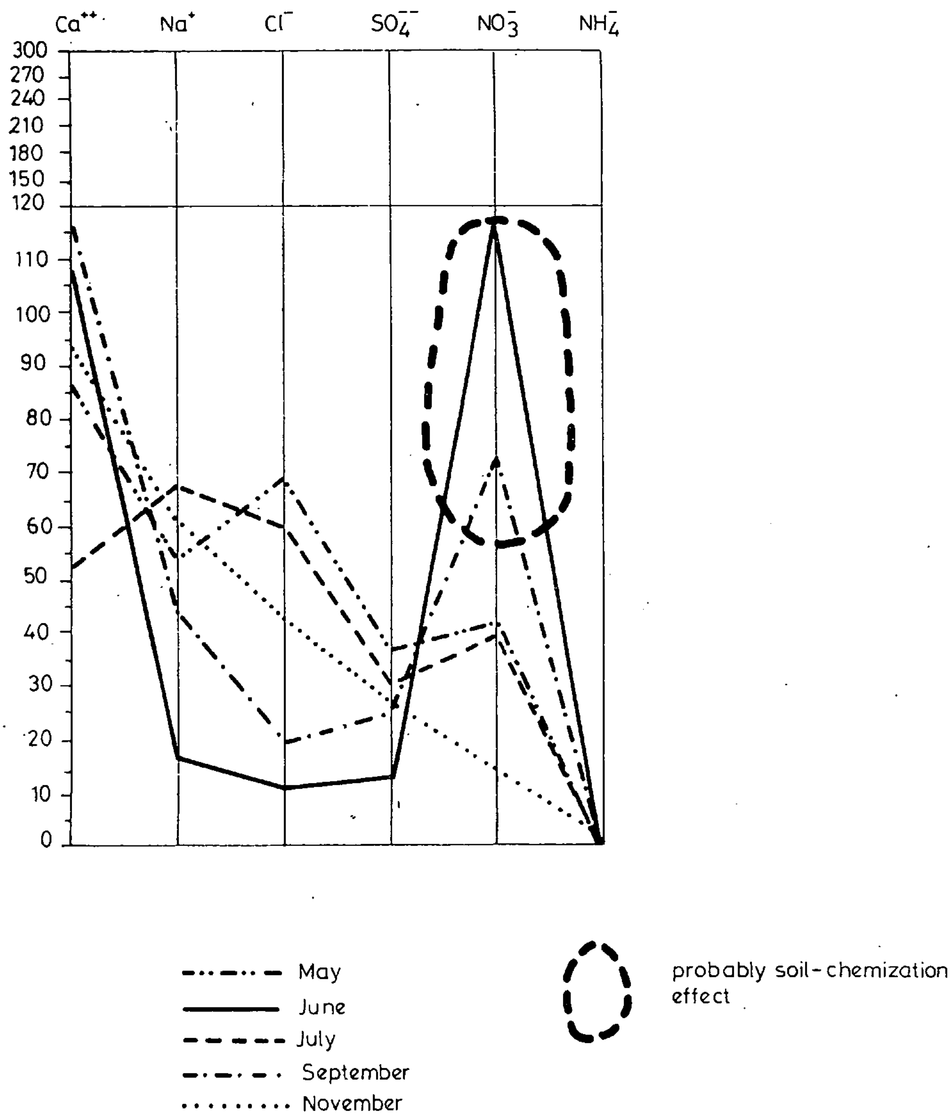
CHANGES IN COMPOSITION OF THE WATER OF SOILWATER WELL NO.1 AT ÜLLÉS

Figure 2.



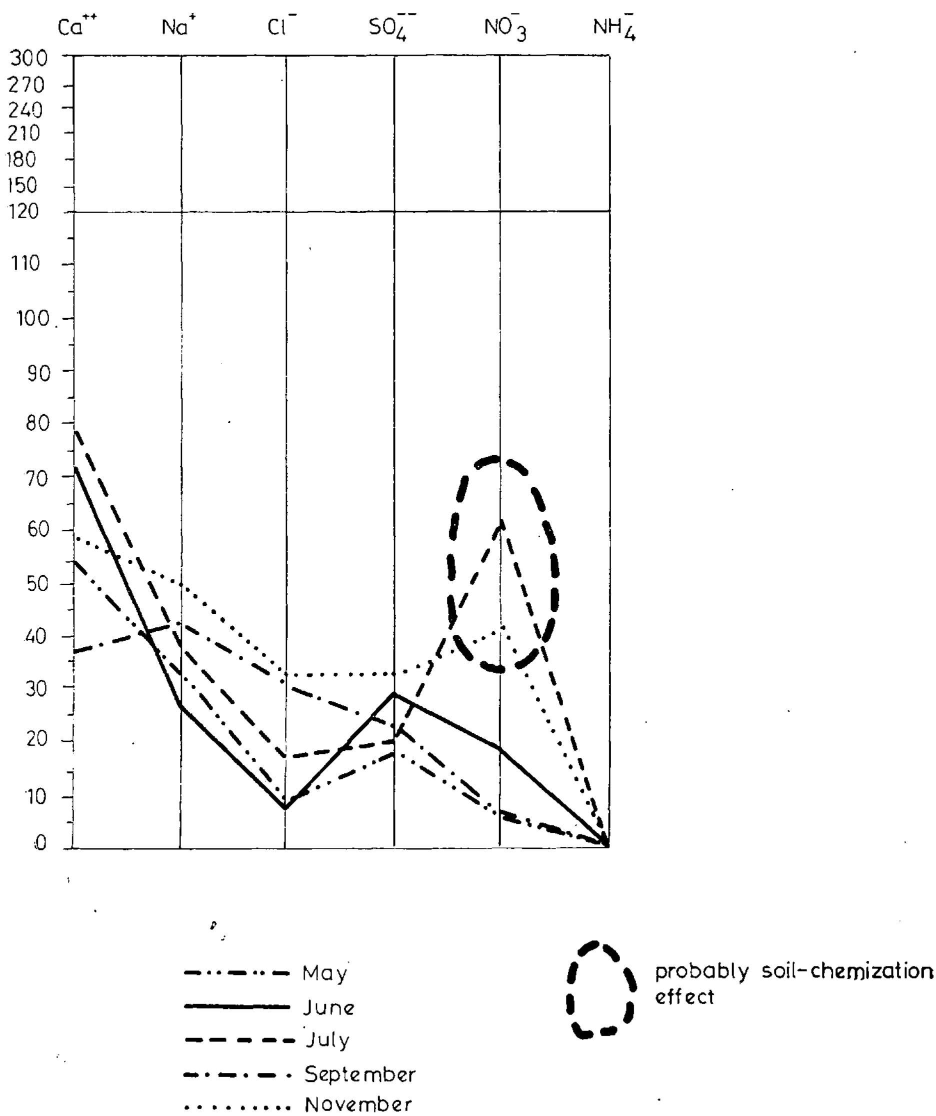
CHANGES IN COMPOSITION OF THE WATER OF SOILWATER WELL NO. 2 AT ÜLLÉS

Figure 3.



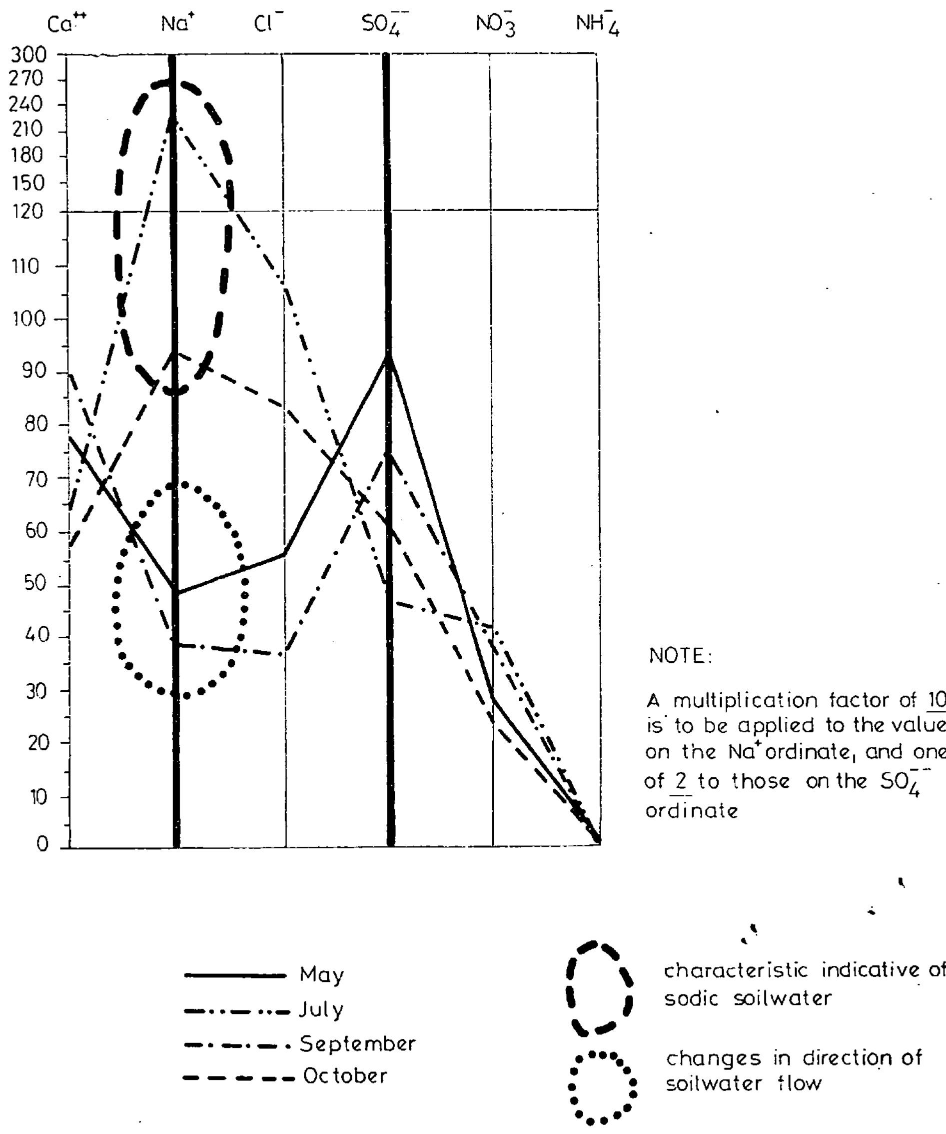
CHANGES IN COMPOSITION OF THE WATER OF SOILWATER WELL NO. 1 AT SZANK

Figure 4.



CHANGES IN COMPOSITION OF THE WATER OF SOILWATER WELL NO.1 AT TÁPÉ

Figure 5.

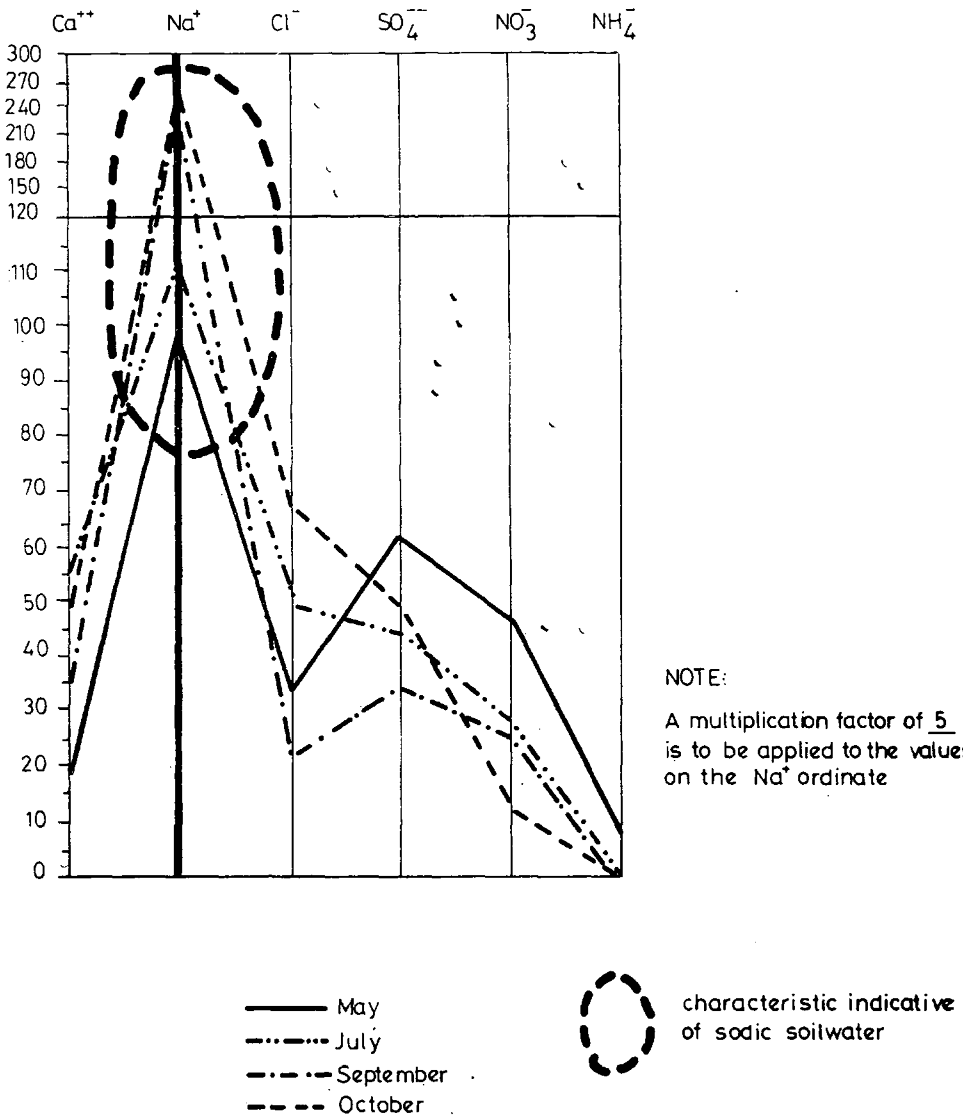


NOTE:

A multiplication factor of 10 is to be applied to the values on the Na^{+} ordinate, and one of 2 to those on the SO_4^{--} ordinate

CHANGES IN COMPOSITION OF THE WATER OF SOILWATER WELL NO. 2 AT TÁPÉ

Figure 6.

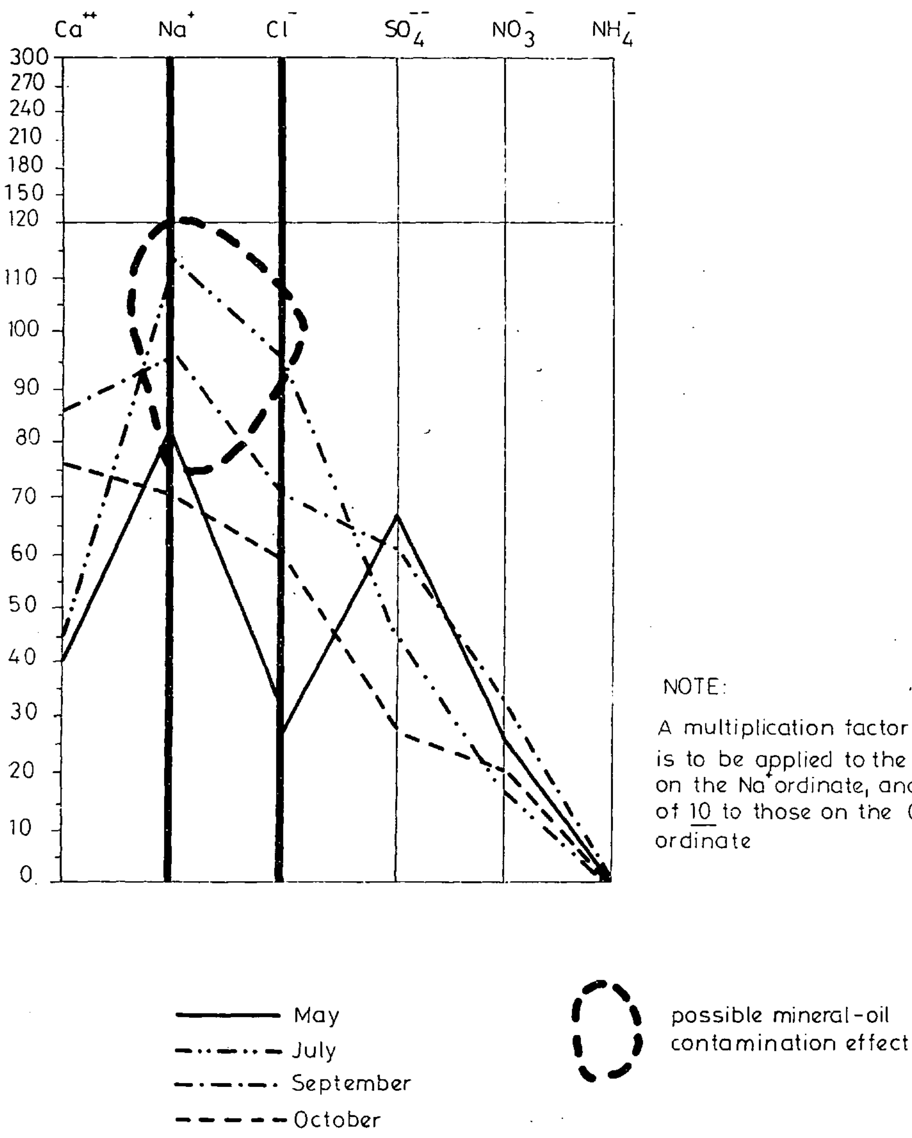


NOTE:

A multiplication factor of 5 is to be applied to the values on the Na^{+} ordinate

CHANGES IN COMPOSITION OF THE WATER OF SOILWATER WELL NO. 1 AT ALGYŐ

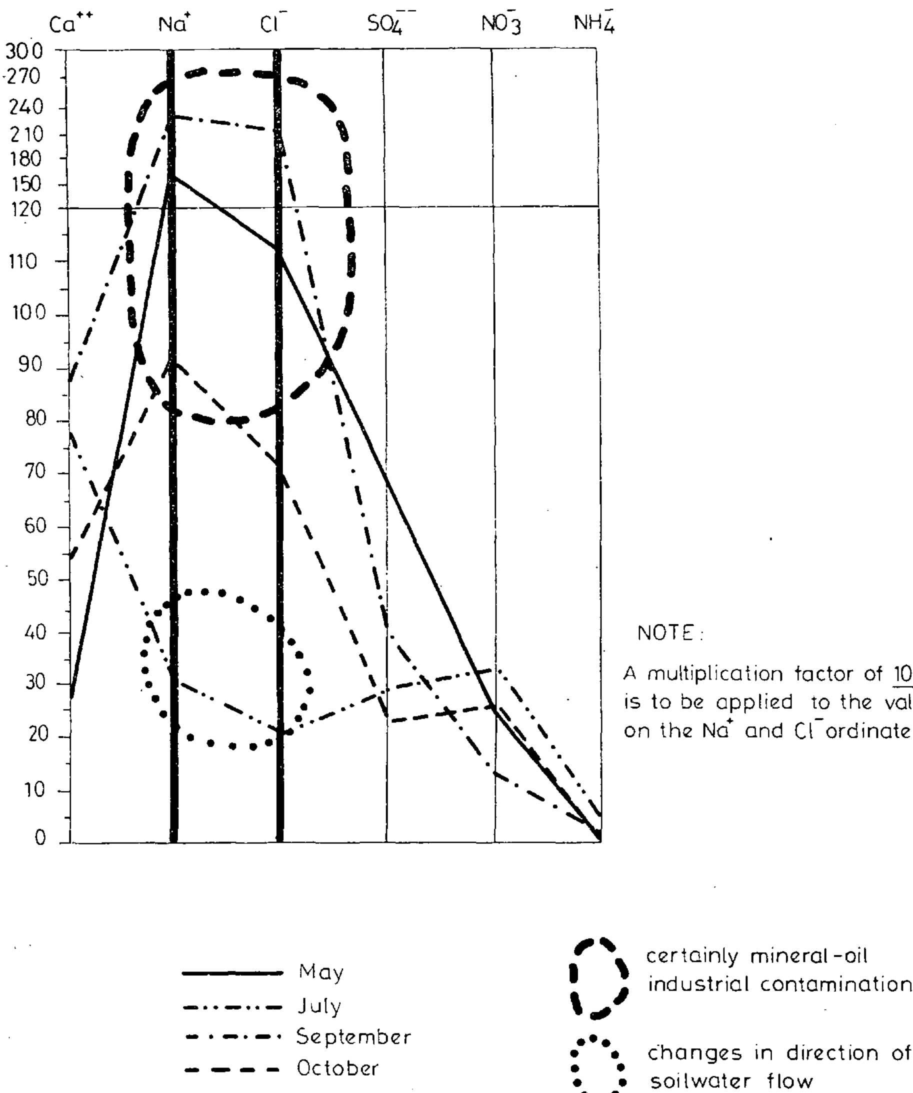
Figure 7.



NOTE:
A multiplication factor of 5 is to be applied to the values on the Na^{+} ordinate, and one of 10 to those on the Cl^{-} ordinate

CHANGES IN COMPOSITION OF THE WATER OF SOILWATER WELL NO. 2 AT ALGYŐ

Figure 8.



NOTE: A multiplication factor of 10 is to be applied to the values on the Na^+ and Cl^- ordinates inwashing is particularly great on the occasion of more severe summer storms, when oil seepages which have accumulated for even several months may suddenly be washed into the soil by the rain. However, even in these cases our examinations did not disclose the presence of mineral-oil derivatives in the soil-waters.

The cause of the negative results is probably to be found in the fact that even where the soil has a good permeability, it effectively filters out the oil content of the infiltrating water. Thus, the oil either does not reach the soil-water level at all, or if it does, then only after a delay and over a long drawn out period; because of the water exchange within the layers, ensured by the given soil-water flows, this leads to dilution of the oil until it is practically undetectable.

As documented by the results of the soil examinations to be presented below, the oil which infiltrates into the soil (even in the case of sandy soils) adheres so strongly to the surface of the individual mineral particles that it can be detected on them even years later. For just this reason, the composition of water flowing through such a layer is not modified by the oil.

From another aspect, the results permit the conclusion that the running-off of oil-industry waste waters can affect the concentrations of sodium and chloride ions in the soil-waters. In the case of coarse grained sand with a good conducting capacity, the increase of the chloride content of the soil-waters can be detected in the direction of flow of the soil-water, sometimes even at a distance of several kilometres from the site of infiltration of the waste water. However, the observed increase in the NaCl concentration of the soil-water has so far not proved to be of an extent harmful to the water in even a single case. A harmless chemical is involved, and at the dilutions observed the question is rather only of theoretical importance.

The characteristics of the water of the individual soil-water wells as regards chemical composition can not always be interpreted with certainty. Indeed, it is not possible to draw clear-cut conclusions even from the considerable increases in the sodium and chloride ion concentrations, for these uppermost soil-waters react extremely sensitively to many chains of factors which are still not satisfactorily understood; we are in the main still unable to perceive suitable connections between all the effects. As illustrated by the composition-modification diagrams, even at a given well within a short time the quality of the water may change to a very large extent, the difference being similar to that observed earlier between two widely-separated wells. Here we think primarily of the decisive role of the great variational possibilities of the following modifying factors:

1. The variable direction of the soil-water flow, which depends on the regional distribution of the precipitation conditions, on the local magnitudes of the running-off and the output, etc.
2. The regionally different evaporation losses of the soil-water surface, affected by the plant cover, the soil-surface state, etc.
3. Factors affecting the local differences in output of the infiltration supply, varying from time to time (fresh ploughland, stubble, meadow, area of growing crops, etc.).
4. Concrete petrological and mineral-composition features of the main infiltration zone, frequently modified even locally.
5. Not least of all the regionally applied artificial fertilizers, insecticides and other anthropogenous chemization.

Naturally, the variation of by and large these same factors also has the result that synchronously taken water samples from soil-water wells sunk in the immediate vicinity of one another frequently exhibit significant differences. As an illustration of this, we present the following example (see Table 2).

TABLE 2.

Results of water-chemical examinations of two soil-water wells (separated by 60 m) of Kálmán Kabna (Domaszék, Tanya 243)

Component	Unit	Well 1	Well 2
alkalinity	W°	9.6	9.5
total hardness	Gh°	22.6	48.2
calcium	mg/l	45.6	109.1
sodium	mg/l	50.6	51.6
chloride	mg/l	70.9	55.0
sulphate	mg/l	102.0	346.0
total dissolved salt	mg/l	880.0	1110.0
oxygen consumption	mg/l	10.4	9.9
ammonium ion	mg/l	0.6	0.5
nitrate ion	mg/l	25.0	33.3

Overall, therefore, it must be stated that as a result of the spontaneous natural factors and the intensive agrogenous interventions, there are such extreme fluctuations in composition in the soil-waters of the South Hungarian Plain that, in comparison, the effects of possible and local oil contaminations can not be distinguished convincingly, even by means of examinations specifically aiming at this.

The situation is entirely different with oil-contaminations on the various types of soils, for it appears very probable that the hydrocarbons infiltrating into the soil will be detectable for many decades, even in the layers where the concentration of the original contamination was only slight: it is only with extreme difficulty that the high molecular weight hydrocarbons bound to the colloidal soil particles and adhering as a film of molecular thickness to the surface of the individual larger mineral grains are broken down to soil. Our regional examinations have proved that there are sharply delineated changes in the structural properties of the soil and in the various functional characteristics of the soil life, even when it is hardly possible to detect the presence of the hydrocarbon in the soil by the customary physical and chemical examination procedures.

In order to assess the characteristics of a soil zone contaminated with hydrocarbon in comparison with a soil zone of the same composition, but not contaminated, a multichannel control investigation was performed at several points on the South Hungarian Plain in the year following the contamination. Soil from the selected points was subjected to laboratory examination for determination of the carbon, humus and hydrocarbon contents. Measurements of the changes in the soil strength and microclimatological analyses were also carried out on site, in an effort to establish the lasting modifications in the biofunctions and dynamics of the soil.

The results are reported below.

The main areas of our examinations were the following:

1. environment of bore no. 1 at Tápé;
2. environment of bore no. 4 at Üllés; and
3. environment of bore no. 4 at Szank.

Apart from these complex station environments, however, further examinations were also made in the regions of Algyő and Kardoskút.

Soil-genetic maps of the complex station environments are given in Figs. 9—11, on the basis of the data of Géczy.

Low-depth drillings were bored in all three test environments, and with the aid of these examinations were made of those components of the various soil levels from which conclusions can be drawn as to the present extent of the hydrocarbon contamination. The positions of the soil-analysis drillings bored in the environment of well no. 1 at Tápé are shown in Fig. 12, together with the results of the laboratory measurements. Figures 13 and 14 show the corresponding data from the environments of bore no. 4 at Üllés and bore no. 4 at Szank, respectively.

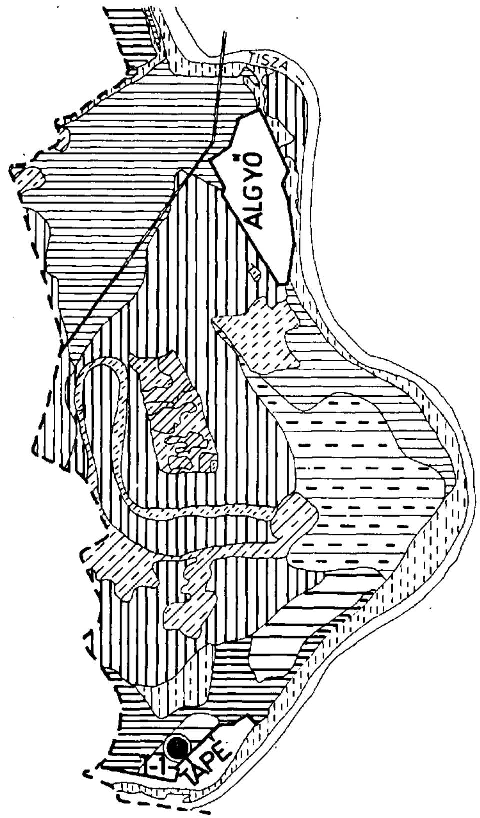
Microclimate stations too, recording soil and air temperatures, were established by M. Andó in the South Hungarian Plain sampling areas selected for study, and these were used to record a full series of temperatures, at hourly intervals, on a hot summer day. His results proved very interesting, for they were very characteristic, even at those points where the soil had been contaminated with only a small amount of hydrocarbons, and years earlier.

From a study of the thermal-conductance heating-up properties of levels with different soil-depths, in practically every characteristic soil type occurring in this region, it emerged everywhere that *the thermal conductivity of soils contaminated at some time with oil had deteriorated substantially.* Consequently, the upper soil layers (those exposed directly to irradiation) heat up very strongly, but at the same time they are able to transmit this amount of heat to the deeper levels only in part, and even then only with a certain delay.

In every other case too there is a phase delay in the heat transfer towards the deeper layers, this being in proportion to the thermal-conductance capacity of the rock-material of the layer. In soils contaminated with hydrocarbon, however, independently of the petrological facies of the soil, this delay increases considerably. These characteristics are well demonstrated by the daily temperature curves recorded on the sodic muddy soil in the region of Algyő (see Figs. 15 and 16), but essentially the same is observed at the other stations too.

Figures 17 and 18 present the observations from the station on meadow clay at Algyő. Here the poor thermal conductivity of the contaminated soil appears even more markedly for the individual soil levels (2, 5, 10, 20 and 30 cm). Whereas the phase delay between the daily temperature maxima of the uppermost and the 30 cm soil levels is only 5 hours in the uncontaminated soil, in the oil-contaminated clay soil the corresponding value is 14 hours.

The effect of contamination on the thermal household of the soil was examined on the muddy loess soil in the region of Kardoskút. In this case too the overall result agreed with those from the stations in the region of Algyő. Since the air temperature too was measured at different levels here, however, the data are plotted in the form of isopletes (see Figs. 19 and 20). In these temperature curves it can also be seen that the radiation reflection heating-up characteristics of the air are likewise affected by the oily contamination of the material of the soil, in so far as



SOIL-GENETIC MAP OF HYDROCARBON AREA BETWEEN ALGYŐ AND TÁPÉ (AFTER GÉCZY)

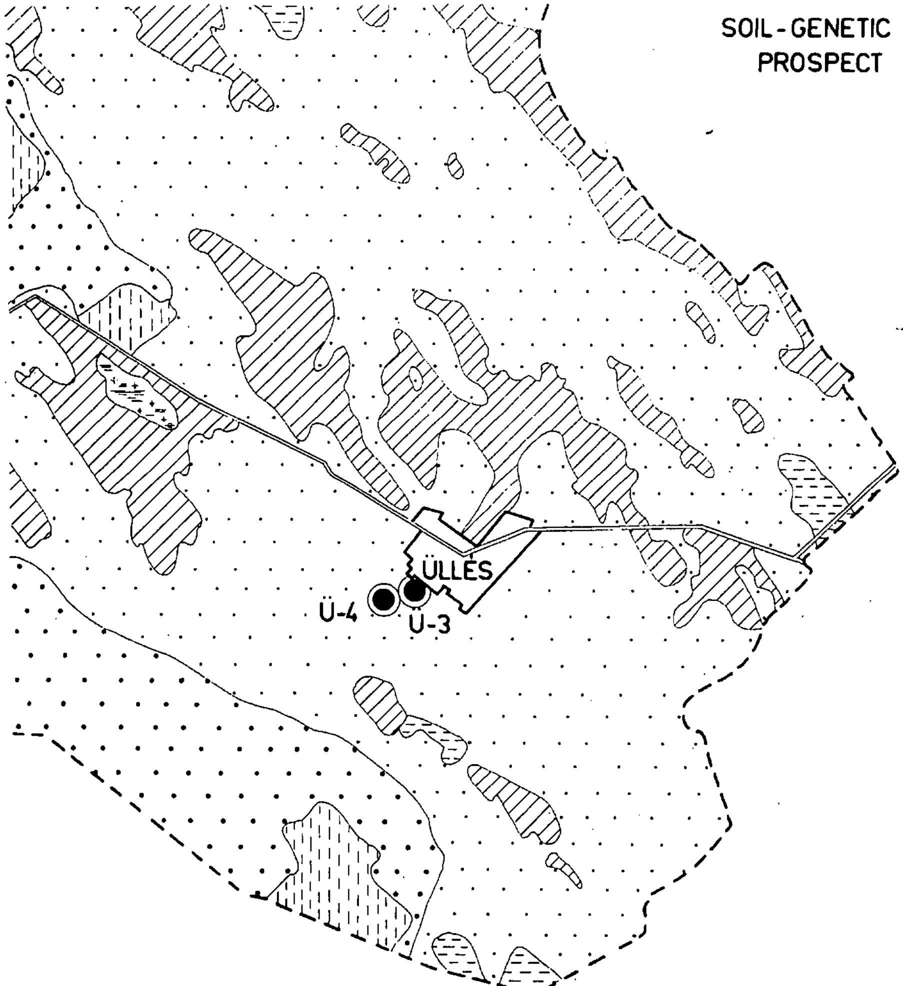
Figure 9.

- light adobe, grassland soil formed on meadow soil
- adobe, grassland soil formed on meadow soil
- sodic adobe, grassland soil formed on meadow soil
- meadow clay, of inundation origin
- inundation clay
- clay of alluvial origin
- heavy clay, grassland soil formed on meadow soil
- clay formed on sodic subsoil of inundation origin
- arable sodic soil formed on meadow soil
- arable sodic soil conditionally formed on meadow soil
- barren sodic soil formed on meadow soil
- woodland
- T-1 hydrocarbon prospect drilling

0 2 4 km

SOIL-GENETIC MAP OF ENVIRONMENT OF HYDROCARBON PROSPECT DRILLINGS NOS. 3 AND 4 AT ÜLLÉS

(AFTER GÉCZY)



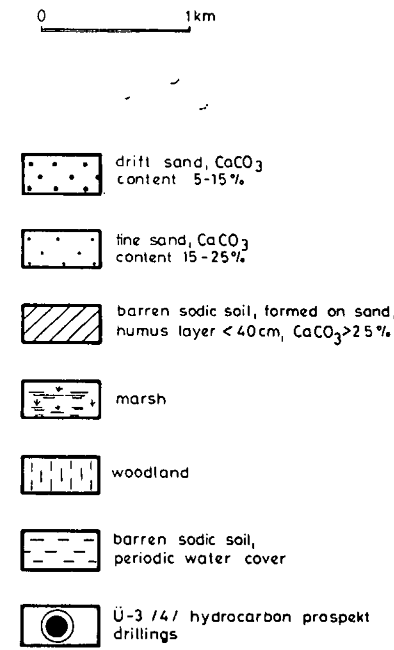


Figure 10

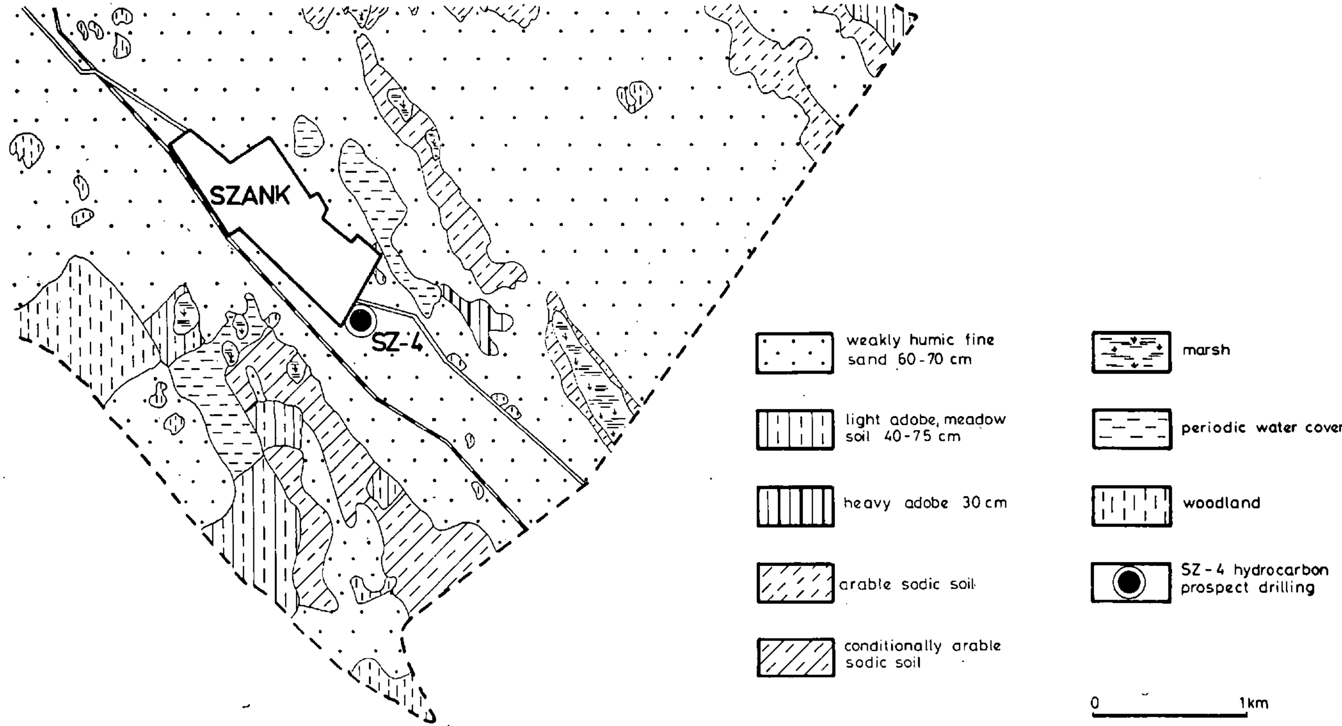
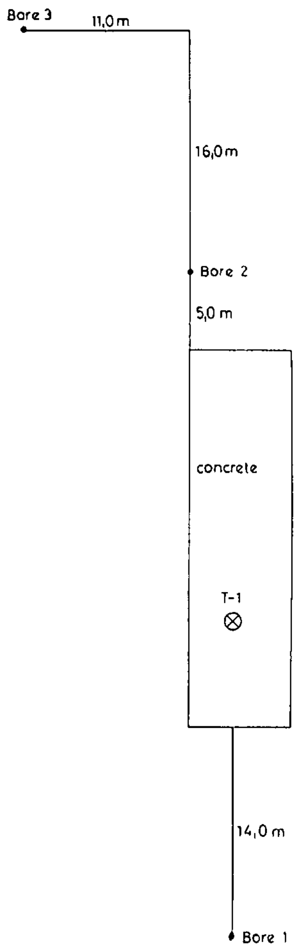


Figure 11.

SOIL-GENETIC MAP OF ENVIRONMENT OF HYDROCARBON PROSPECT DRILLING NO. 4 AT SZANK (AFTER-GÉCZY)

SITE - PLAN



Layer sequence of bore 1	SAMPLE depth	symbol	carbon content %	humus content %	hydrocarb. content %
brownish - blak humic clay 0,40	-0,20	T-1/1	1,63	2,82	much
yellowish brown humic clay 0,55	-0,45	T-1/2	1,27	2,00	∅
yellow mud (0,80)	-0,60	T-1/3	0,48	0,83	∅

Layer sequence of bore 3	SAMPLE depth	symbol	carbon content %	humus content %	hydrocarb. content %
brown humic clay 0,35	-0,20	T-3/1	0,98	1,68	∅
brownish yellow clay 0,45	-0,40	T-3/2	0,63	1,08	∅
yellow mud (0,80)	-0,55	T-3/3	0,48	0,83	present

Layer sequence of bore 2	SAMPLE depth	symbol	carbon content %	humus content %	hydrocarb. content %
brownish black humic clay 0,25	-0,20	T-2/1	1,59	2,76	very much
yellow clay 0,50	-0,35	T-2/2	1,28	2,21	much
yellow mud (0,80)	-0,55	T-2/3	0,42	0,73	present

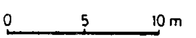
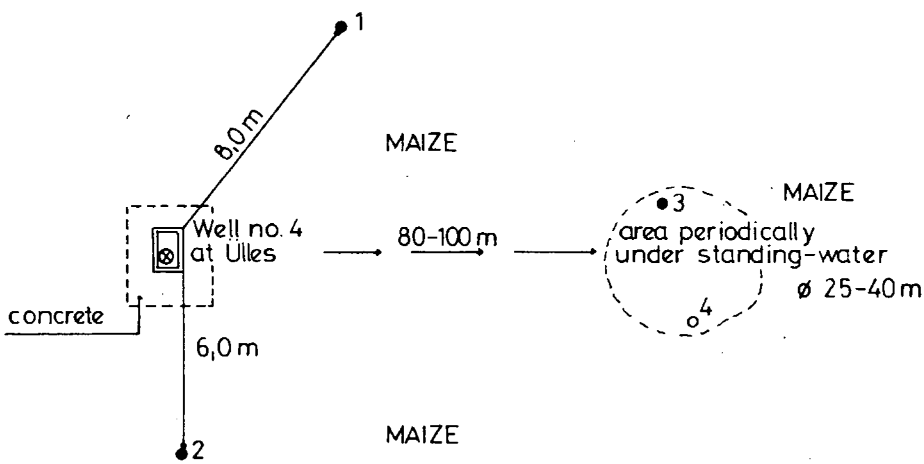


Figure 12.

Humus and hydrocarbon contents of soil samples taken form area of infiltration of hydrocarbons from water prospect drilling no. 1 at Tápé

SITE - PLAN

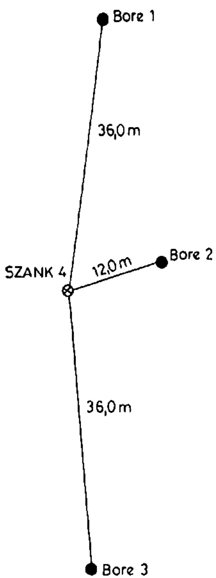


SAMPLES TAKEN FROM SURFACE			
symbol	carbon content %	humus content %	hydrocarbon content %
Ü 4/1	0,680	1,17	present
Ü 4/2	0,623	1,07	present
Ü 4/3	0,954	1,65	present
Ü 4/4	2,483	4,30	present

Figure 13.

Humus and hydrocarbon contents of soil samples taken from the surface, 11 years after gushing of hydrocarbon prospect drilling no. 4 at Ülles

SITE - PLAN



Layer sequence of bore 1		SAMPLE depth	symbol	carbon content %	humus content %	hydrocarb. content %
yellow fine 0,30	muddy sand	-0,05	SZ-1/1	0,521	0,90	present
yellowish muddy 0,4	brown fine sand	-0,35	SZ-1/2	0,285	0,49	Ø
brow sand 0,70	fine	-0,50	SZ-1/3	0,534	0,92	present
yellow sand	fine (0,85)	-0,80	SZ-1/4	0,051	0,09	Ø

Layer sequence of bore 3		SAMPLE depth	symbol	carbon content %	humus content %	hydrocarb. content %
some humus	cm	-0,05	SZ-3/1	0,458	0,79	Ø
sand interspersed with and filling	mud lumps humic	-0,20	SZ-3/2	1,745	3,02	present
0,40		-0,35	SZ-3/3	0,589	1,08	present
yellow sand	fine (-0,60)	-0,55	SZ-3/4	0,070	0,13	Ø

Layer sequence of bore 2		SAMPLE depth	symbol	carbon content %	humus content %	hydrocarb. content %
yellow sand- 0,30	fine-sandy dust	-0,10	SZ-2/1	0,437	0,76	present
grey sand 0,45	fine	-0,30	SZ-2/2	0,068	0,12	Ø
yellow sand	fine (0,85)	-0,55	SZ-2/3	0,058	0,10	Ø

0 10 20m

Figure 14.

Carbon, humus and hydrocarbon contents of deepened shallow borings and the individual layers in the vicinity of the hydrocarbon prospect drilling no. 4 at Szank

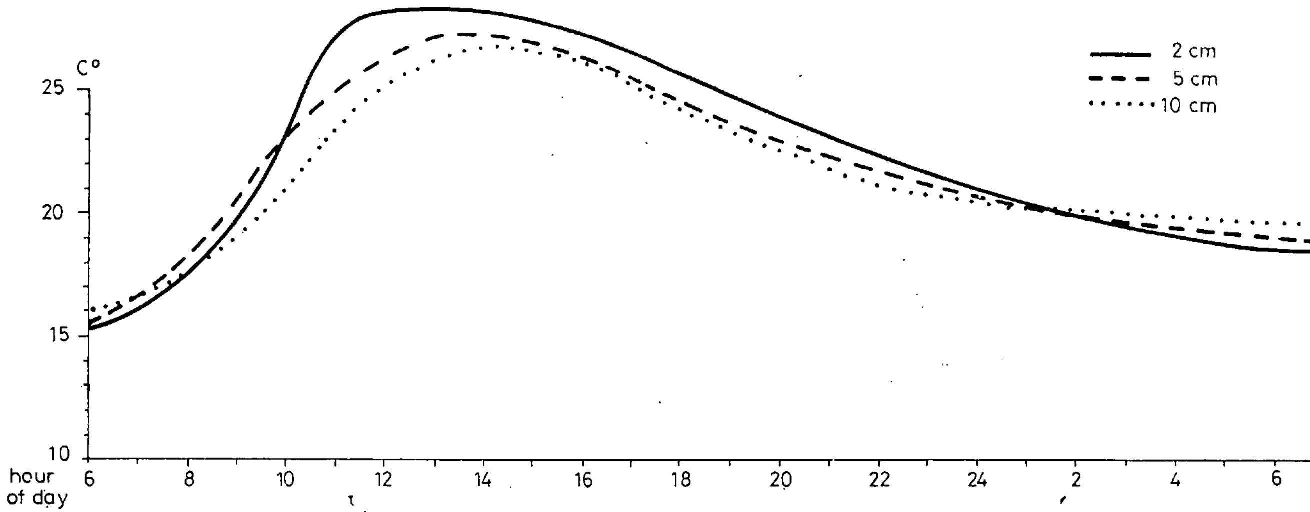


Figure 15

COURSE OF DAILY SUMMER TEMPERATURE OF SODIC MUD-SOIL NOT CONTAMINATED WITH HYDROCARBON, IN REGION OF ALGYŐ

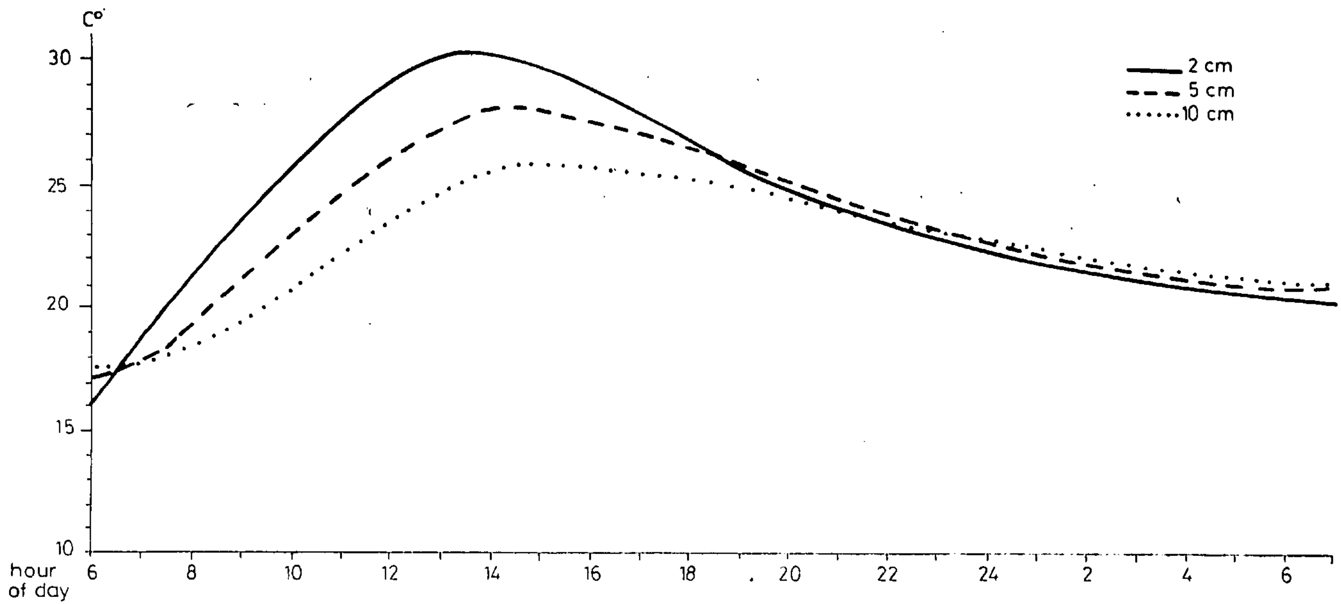


Figure 16.

COURSE OF DAILY SUMMER TEMPERATURE OF SODIC MUD-SOIL CONTAMINATED WITH HYDROCARBON, IN REGION OF ALGYŐ

SOIL-TEMPERATURE STRATIFICATION OF MEADOW CLAY NOT CONTAMINATED WITH OIL, IN REGION OF ALGYŐ

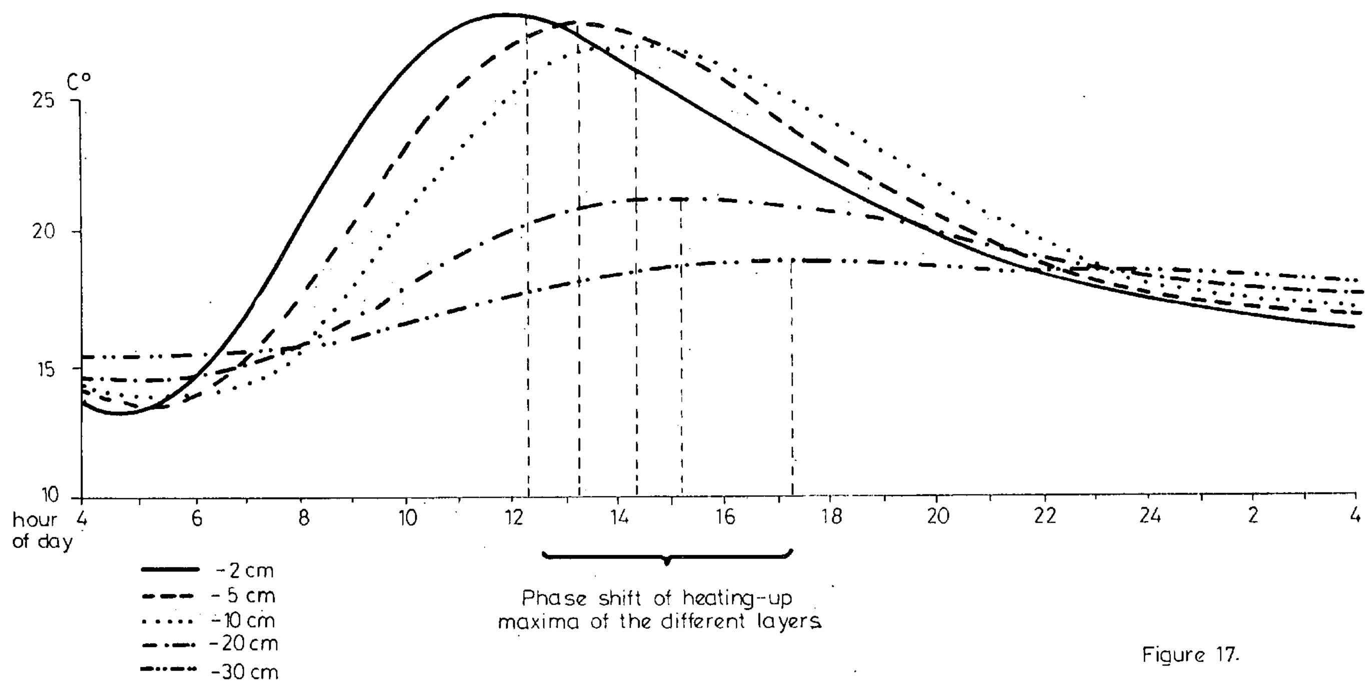


Figure 17.

SOIL-TEMPERATURE STRATIFICATION OF MEADOW CLAY CONTAMINATED WITH OIL, IN REGION OF ALGYÖ

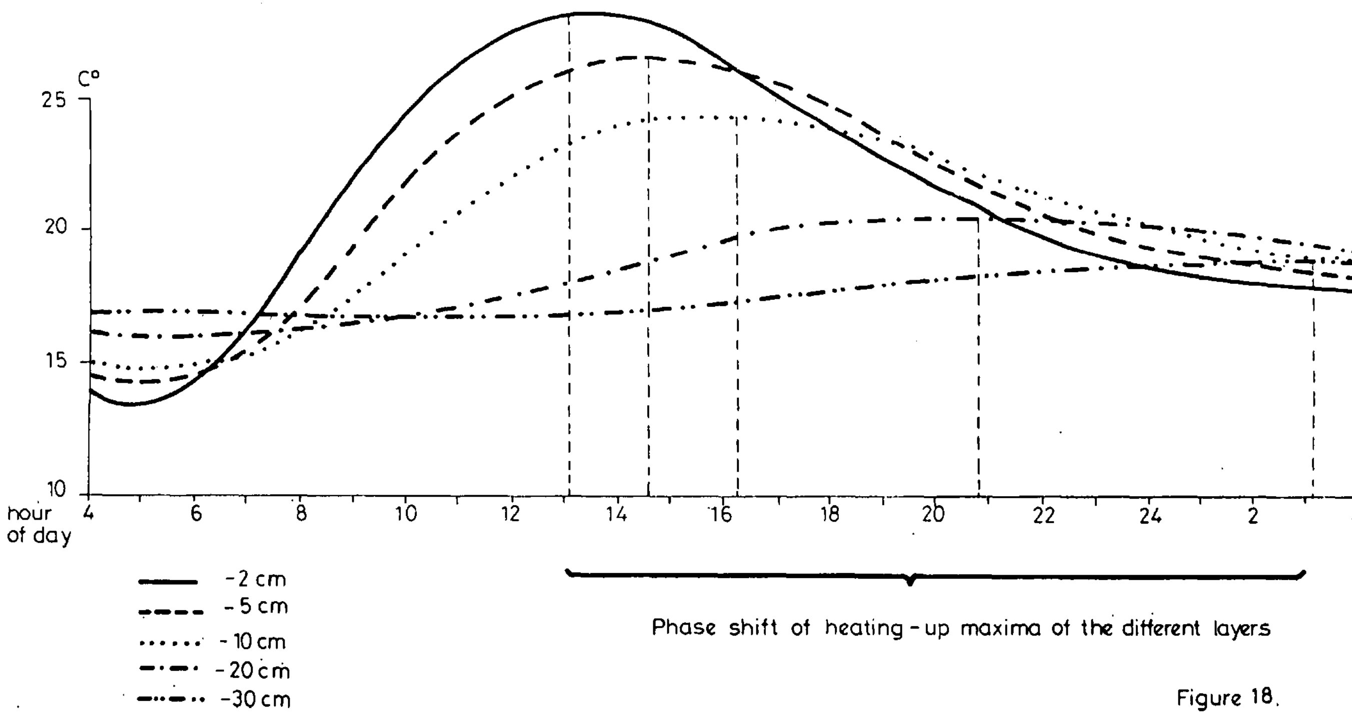
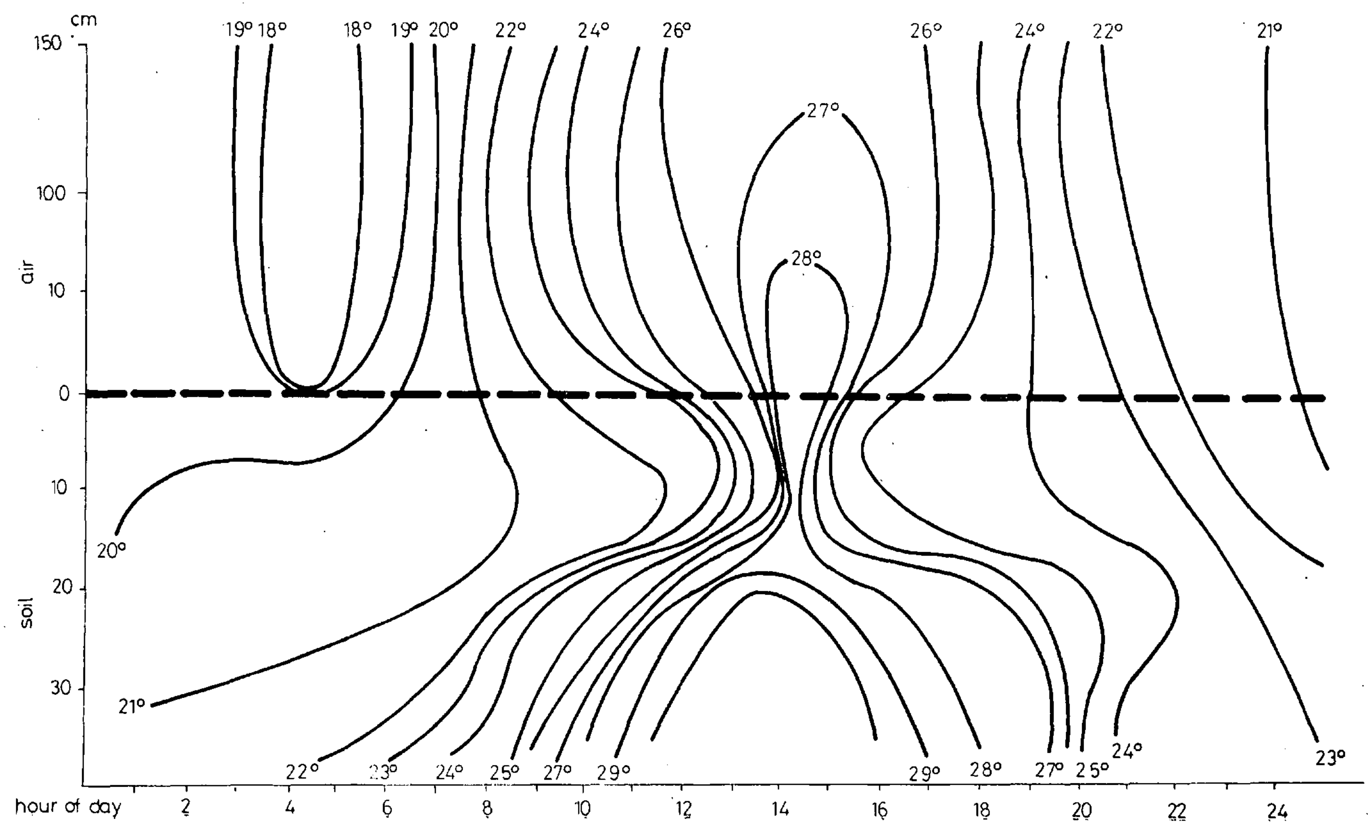


Figure 18.

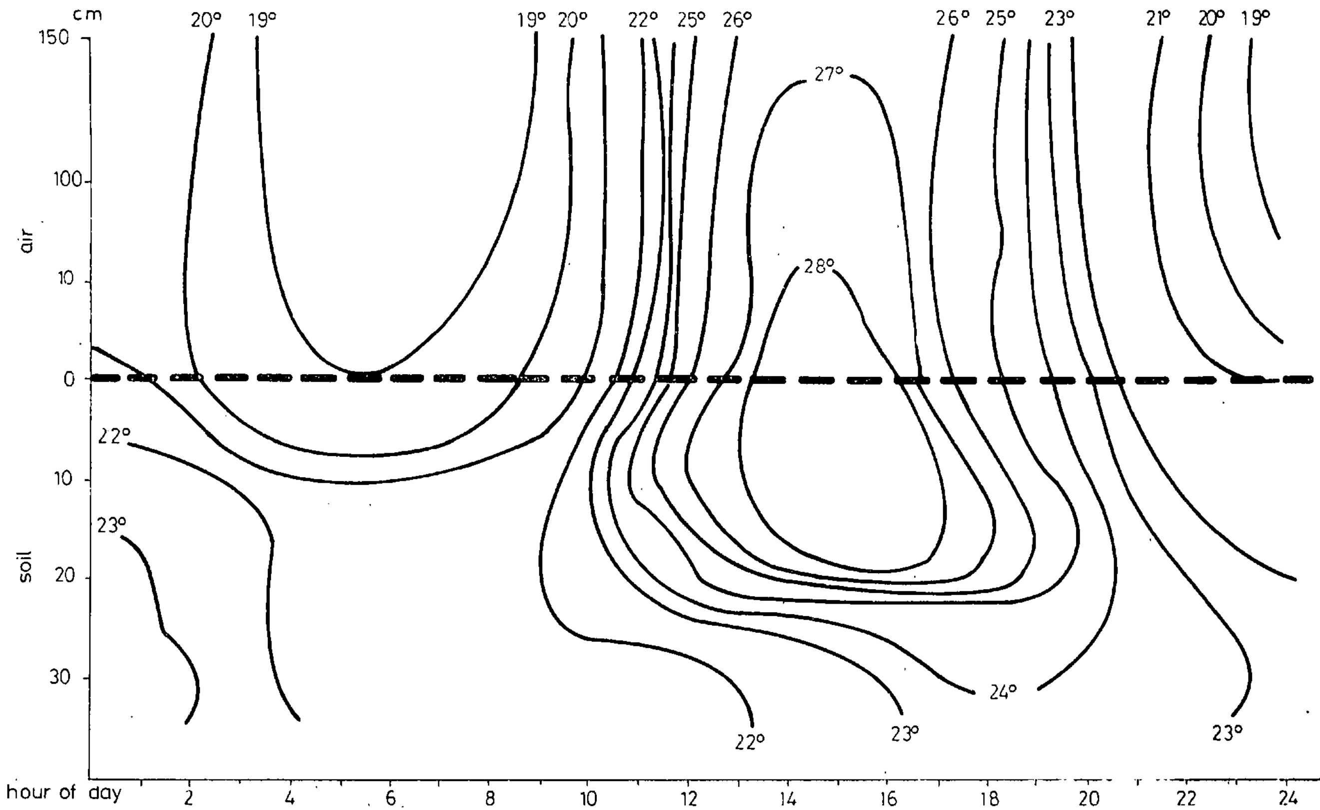
SUMMER TEMPERATURE ISOPLETS OF SODIC MUDDY LOESS SOIL NOT CONTAMINATED WITH HYDROCARBON, IN REGION OF KARDOSKÚT

Figure 19.



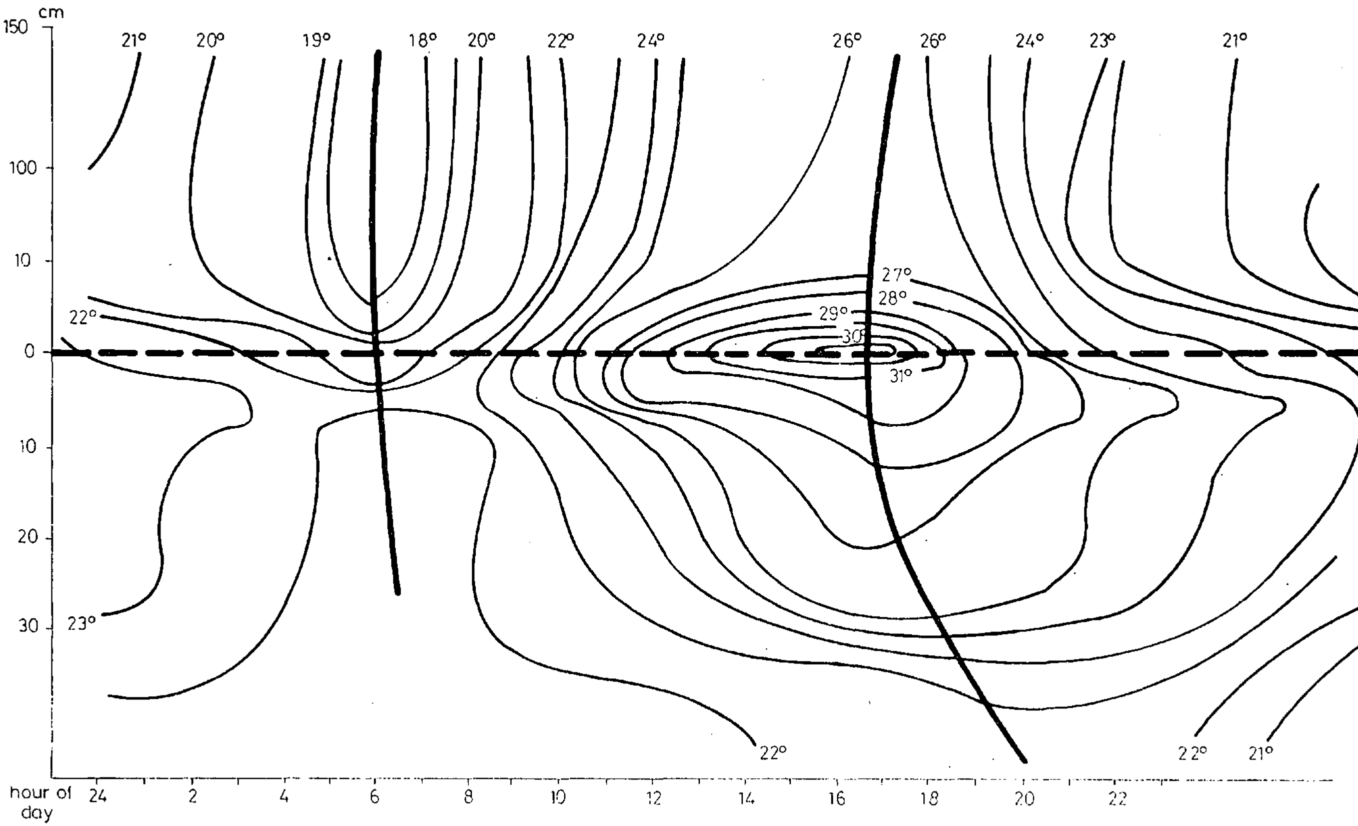
SUMMER TEMPERATURE ISOPLETS OF SODIC MUDDY LOESS SOIL CONTAMINATED WITH HYDROCARBON, IN REGION OF KARDOSKÚT

Figure 20.



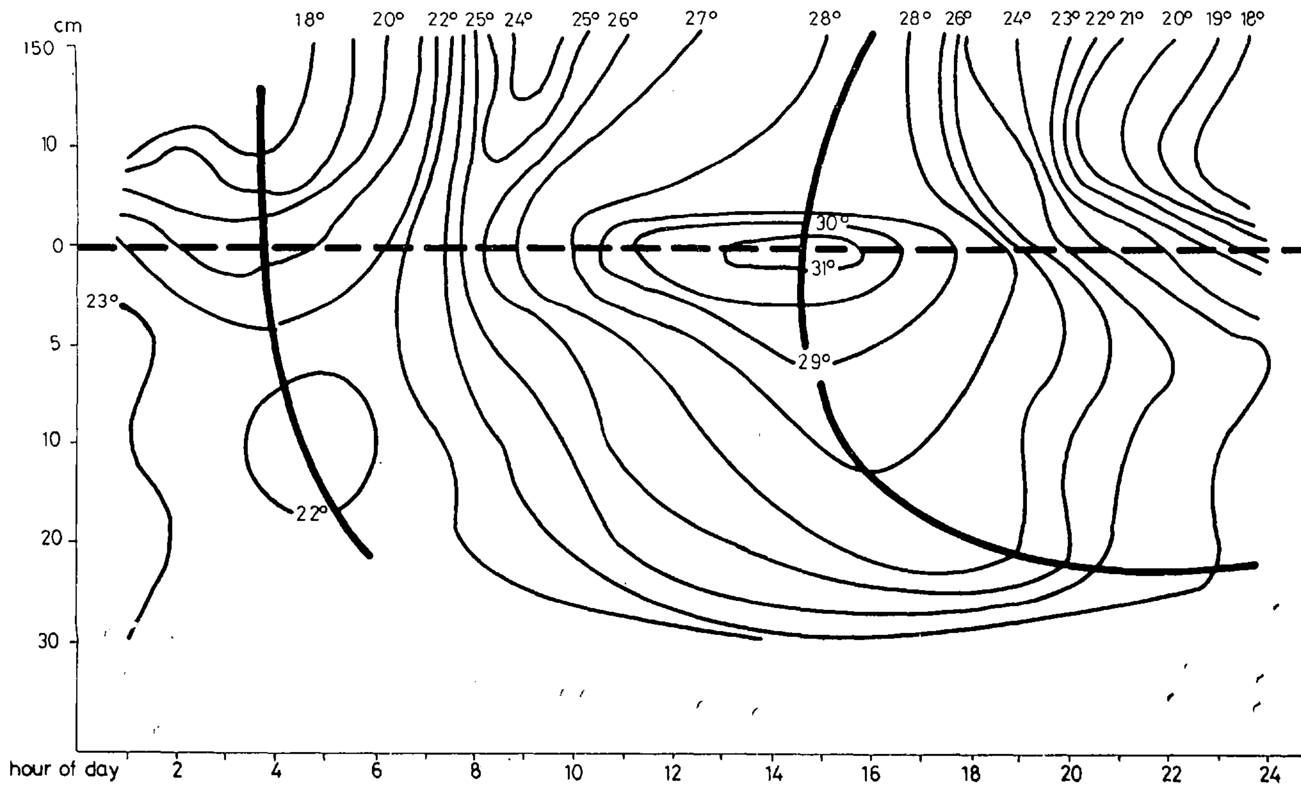
TEMPERATURE ISOPLETS OF MUDDY SAND NOT CONTAMINATED WITH HYDROCARBON, ON A BRIGHT SUMMER DAY AT SZANK

Figure 21.



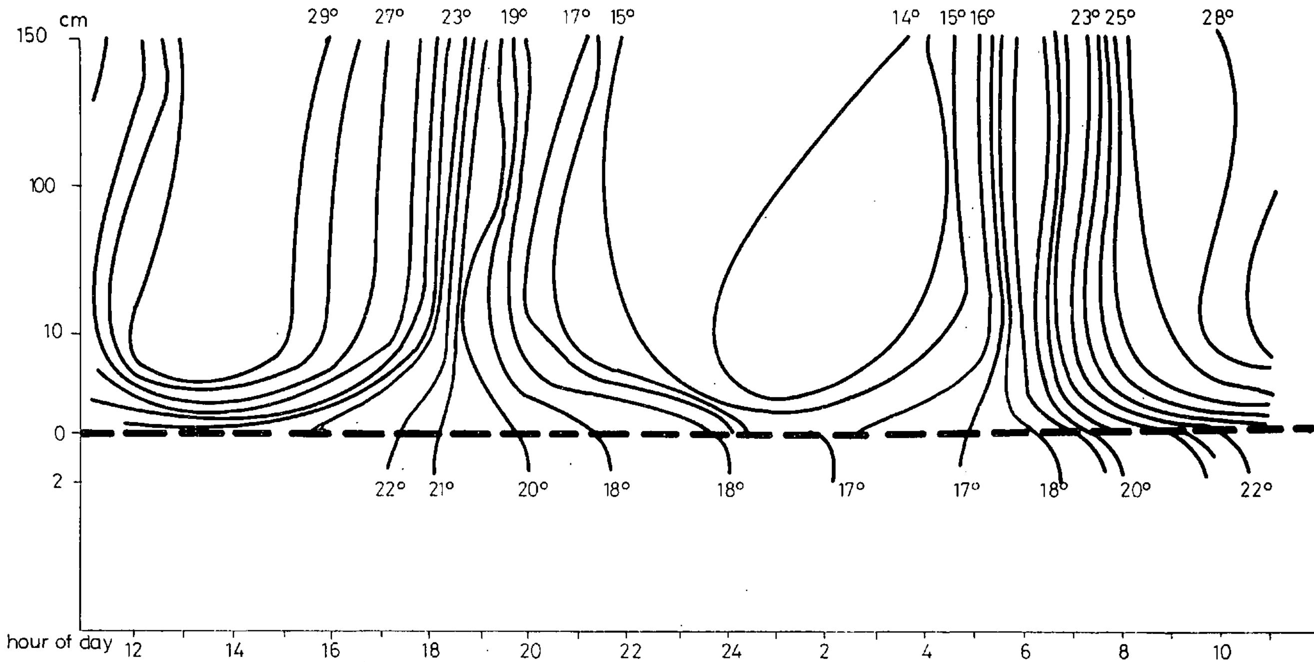
TEMPERATURE ISOPLETS OF MUDDY SAND CONTAMINATED WITH HYDROCARBON, ON A BRIGHT SUMMER DAY AT SZANK

Figure 22.



SUMMER TEMPERATURE ISOPLETS OF SANDY SOIL NOT CONTAMINATED WITH HYDROCARBON, IN THE REGION OF ÜLLÉS

Figure 23.



SUMMER TEMPERATURE ISOPLETS OF SANDY SOIL CONTAMINATED WITH HYDROCARBON, IN THE REGION OF ÜLLÉS

Figure 24.

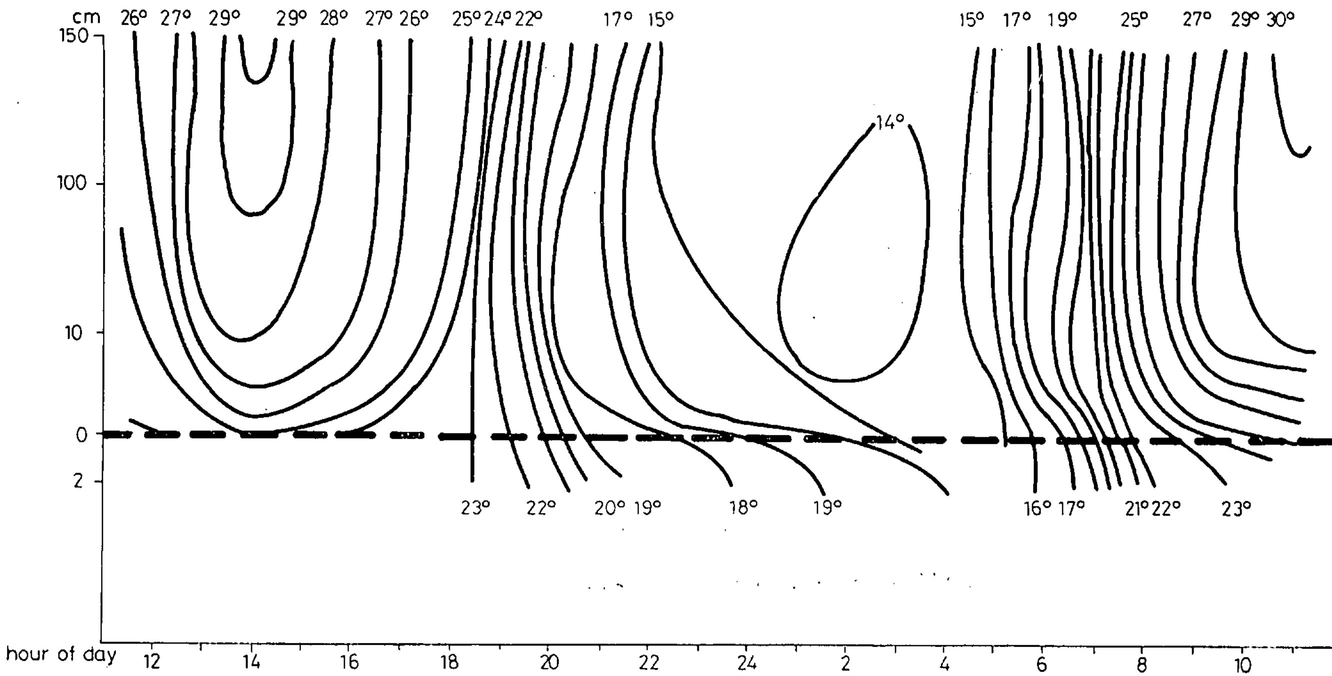


Fig. 25. Sandy soil transformed to desert in a maize field near Üllés on the action of mild oil-contamination. Only xerophyte semi-desert weeds remain on the bare patch.

the contaminated soil, with its poor thermal conductance capacity, and which therefore heats up strongly on the surface, ensures a more intensive radiation heat transfer to the air layer adjacent to the soil.

The mud mass which poured onto the surface on the occasion of the gushing in 1965 in the environment of bore no. 4 at Szank built up an entire, definitely perceptible, flattish hillock. Although the material of this has since been carted away and covered, nevertheless the contamination of the soil by hydrocarbon can clearly be seen on the sand. The daily temperature isopletes recorded here and on a nearby uncontaminated sandy area are shown in Figs. 21 and 22. These confirm that as a result of the oily contamination the sandy soil too changes its thermal household characteristics in the manner already discussed in connection with the more heavy soils.

As regards the Üllés sand, soil-temperature data exist only for a depth of 2 cm, but a whole series of air-temperature layer diagrams are available on the thermal household characteristics of the hydrocarbon-contaminated and uncontaminated sandy soils (see Figs. 23 and 24). These data support the earlier conclusions.

Accordingly, it is not at all surprising that *the plants are generally scorched in the oil-contaminated soils.* There are very few agricultural plants which are well able

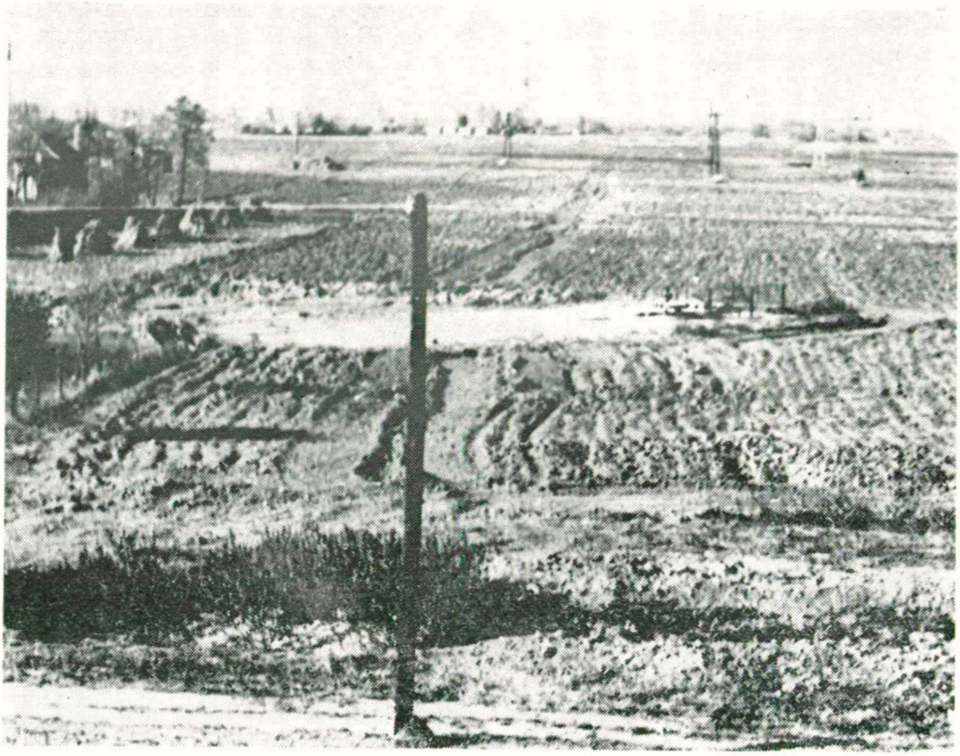


Fig. 26. A small naphthogenetic desert formed in the environmentof a drilling in 1972 at the edge of the village of Tápé, as a result of oil dripping from the mechanical installations. This has made the area so barren that it has not been cultivated since then.

to endure the considerable temperature differences at the various levels of the rhizosphere, which are typical in the heating-up period of the day, that is the morning, in hydrocarbon-contaminated soils. The nature of the soil here, and to some extent the air layers above it too, is reminiscent of desert conditions. The difference is simply that these deserts produced locally by the action of the oil are not climatogenetic deserts, but lithogenetic ones, and their characteristic differences in microclimate too are reflections of the soil effect.

In Figs. 25—27, therefore, some small "lithogenetic desert spots" are presented, the unproductiveness of which can not yet be eliminated by the chemization and irrigation methods known at present. Since such bare spots are undoubtedly caused by the oil contamination, however, they might justifiably be termed "naphthogenetic deserts".

Fortunately, naphthogenetic deserts today cover a very small overall area of the Great Hungarian Plain. The results of our approximate calculations indicate that an area of only about 200 hectares is involved to the south of the valley of the Körös rivers, and on the southern part of the area east of the bed of the Tisza. Even

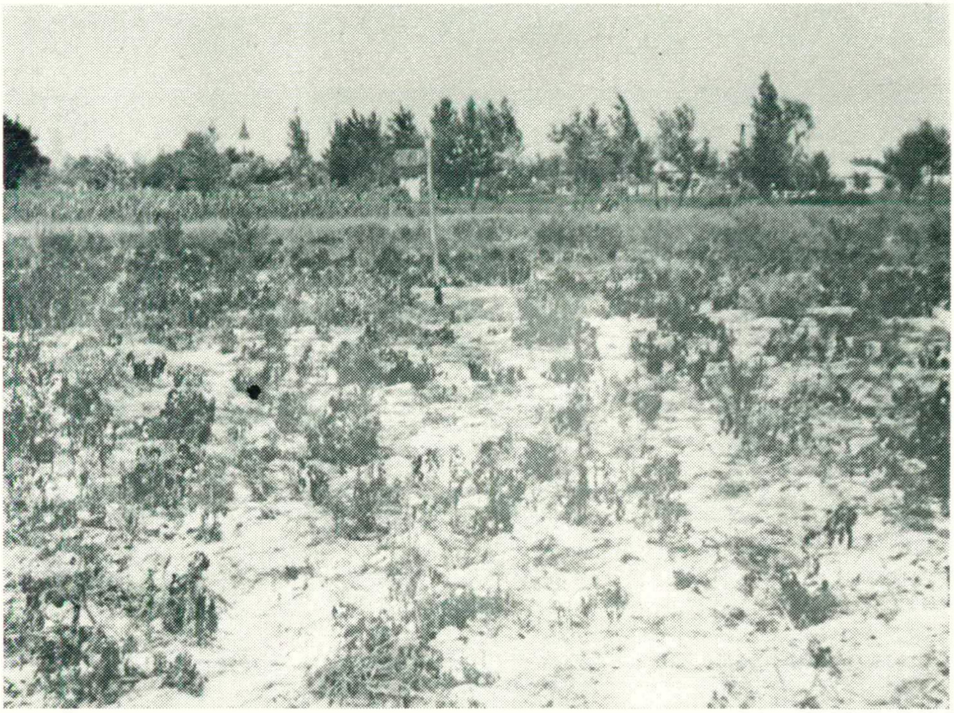


Fig. 27. Experiments in tomato production are now being made on the sandy soil transformed to one with a semidesert microclimate because of hydrocarbon contamination in the environment of bore no. 4 at Szank, with the results to be seen.

this, however, is worthy of attention. In the future, everything must be done to prevent the further spread of these "moon spots" in proportion to the increase of vehicular traffic and hydrocarbon production.