Salt Sources of Alkali Soils in South Slovakia

J. HRAŠKO

Soil Science Laboratory, Bratislava (Czechoslovakia)

The problem of salt sources causing the formation of salt affected soils has been discussed in the pedological literature for a long time. As related by BASILEVIČ [1] in the 18th and 19th centuries numerous authors advanced the theory of the sea-origin of salts. BASILEVIČ remarks, however, that the continental mountain systems are also salt sources and this accounts for salt accumulation in the loose, sedimentary rocks. On studying salt accumulation processes in the soils of the Danube Valley in Hungary, VÁRALLYAY [16] came to the conclusion that the igneous rocks (andesite, rhyolite and mainly their weathered tuffs) of mountains surrounding this plain were the most important primary sources of salts in this territory. The origin of salts in the Slovakian part of the Danubian plain is discussed by ČERVENKA [3] who observed a close connection between the occurrence of salt affected soils and the high water table of mineralized ground waters. In his opinion one of the most important tasks is to reveal the causes of the intense mineralization of ground waters in the region of South Slovakia.

On studying the mineralogical composition of soils and substrata in the Danubian lowland, especially in Žitný Ostrov (Island of Grain), we ascertained the possibility that weathering processes release salts.

The petrographic composition of the Danubian sediments in Žitný Ostrov indicates that they are of Alpine origin. These sediments consist mainly of quartz, quartzite, limestone (calcite), dolomite, and various silicates and, to a lesser degree, schists, sandstones and granitic rocks may also be found in them.

As regards the mineralogical composition of the heavier fraction, the predominance of minerals from metamorphosed rocks (garnet 30—50%, amphibole 10—25%, opaque minerals 10—15%, minerals of the soisite-epidote group 10—15%) is evident. In the light fraction especially calcite, dolomite, various feldspars both from the orthoclase and plagioclase groups (the latter may be found in relatively high amounts), muscovite and different chlorites are dominating, biotite is present in low quantities.

Material and method

A sample was taken from a soil profile at the village of Novy Dvor (Dunajská Streda district) to study the weathering process. This sample represents the parent material of a chernozemic meadow soil; its analytical data are given in Table 1. The mechanical composition of the original sample is presented in Table 2.

The sample was subjected to the following treatments:

Table 1

Chemical analyses of the original sample

pH (H_2O)	Carbonates %	The loss by annealing	Total content, in %									
			SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5
8,25	22,4	18,94	42,34	10,96	5,04	12,30	5,84	1,94	1,19	0,48	0,12	0,13

50 g of the sample was placed in a porcelain dish and water was added until the soil reached the paste state. It was kept in a refrigerator at −30°C for 12 hours, then it was put in a thermostat for 12 hours again, at +40°C. During this latter period the sample was moistened after 6 hours to reestablish its paste state. Thus, when in the refrigerator, the sample was always moist, while at +40°C it was in both dry and moist states. The sample was subjected to the same treatments for 40 days. At the end of every 10-day-period, having defreezed the sample, 125 ml of distilled water was added to it. After mixing and settling, 50 ml of the clear, supernatant solution was pipetted for chemical analyses.

We had a control sample which was neither heated, nor freezed. After 10 days it also received 125 ml of water and then 50 ml of the leachate was pipetted. Having been dried in a thermostat at +40°C, the sample was kept in the laboratory without being subjected to any subsequent treatment for 10 days.

In the obtained extracts K^+ and Na^+ were determined with a flame-photometer, while Ca^{2+} and Mg^{2+} complexometrically.

Having finished the experiment, we carried out again the mechanical analysis of the sample alternately heated and freezed (dispersion with hexametaphosphate, pipette-method) and the clay fraction (smaller than 1 μ) was separated. The clay fraction of the control sample was separated as well.

In the clay fraction the clay minerals were determined by means of a Philips X-ray apparatus used as a diffractometer. Both samples were also studied with an electron microscope.

Table 2

Change of the sample's granularity on weathering

Samples	The fraction in mm					
	2,0−0,2	0,2−0,06	0,06−0,02	0,02−0,006	0,006−0,002	< 0,002
Original sample	1,6	2,7	34,1	31,6	11,4	18,6
After the experiment	1,0	2,1	30,4	33,7	14,1	19,2
Difference	−0,6	−0,6	−3,9	+2,1	+2,7	+0,6

Results and discussion

Alternate freezing and heating, drying and wetting (i.e. the modelling of natural processes) enabled us to observe a specific rock weathering, manifesting itself in the changes of the sample's mechanical composition (Table 2). As the data clearly indicate, due to the effect of prolonged weathering the granulometric composition of the sediments notably changes. The amounts of sand and coarse silt diminished while those of medium and fine silt and, partially, that of clay substantially increased. In our opinion this process, which is called "obl'osovanie" in the Russian literature, may be the cause of

In the pictures prepared by the electron microscope only traces of caolinite, very small quantities of montmorillonite but much illite can be detected (Figure 4) and this also proves that the marked kX 7,12 line does not appertain to caolinite, nor the kX 14,7 to montmorillonite. Figure 4a represents the control sample, whereas Figure 4b was prepared from the sample after the "weathering" process. This picture confirms the diffractometric data indicating considerable increase in the amount of hydromicas after weathering.

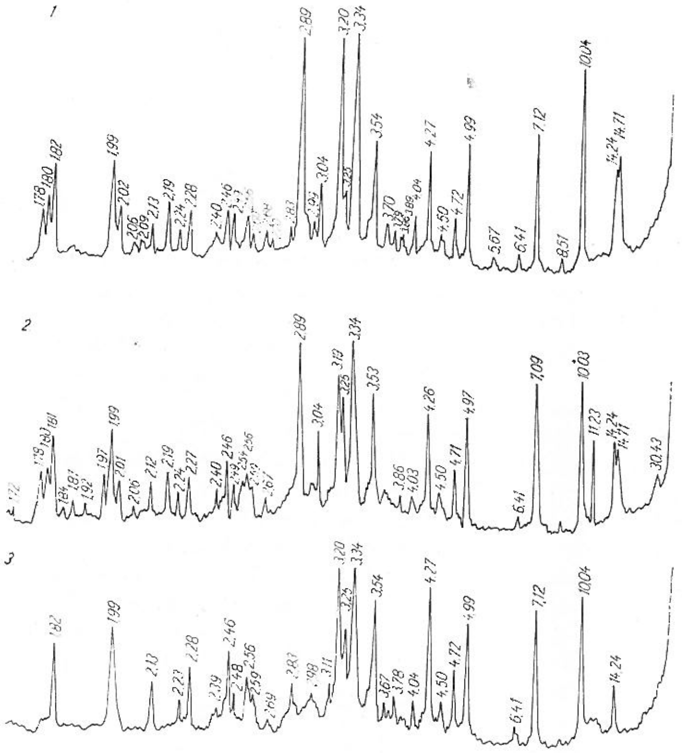

Figure 1

Diffractogram of the whole sample. 1. The original sample. 2. The sample after weathering. 3. The sample after removing the carbonates with 10% HCl

Conclusions drawn for the territory of Žitný Ostrov

Žitný Ostrov is an about 100 km long and 15 km wide island of the Danube, extending from Bratislava to Komarno. The entire island is a young, structural plain created by the alluvial deposits of the Danube, during permanent tectonic sinking. These sediments are relatively young, only the gravel kernel of Žitný Ostrov is considered by numerous authors [12, 13] as pleistocenic. In the upper part of the island the water table is at 6—8 m below the surface (immersed in gravels) while in the lower part it rises to 1—2 m. The direction of the ground water movement is parallel with the Danube, that is, approximately, with the longitudinal section [11]. In general the sediments

Table 3

The quantity of cations released from the weathered sample (a) and from the control (b) (in mval/100 g earth, water extract 1 : 2,5)

Leaching	Ca^{2+}			Mg^{2+}			Na^{+}			K^{+}		
	a	b	a−b	a	b	a−b	a	b	a−b	a	b	a−b
1	0,55	0,30	0,25	0,35	0,19	0,16	1,45	0,85	0,60	0,6	0,5	0,1
2	0,28	0,20	0,08	0,23	0,11	0,12	1,30	0,40	0,90	0,2	0,2	0,0
3	0,42	0,10	0,32	0,30	0,16	0,14	1,20	0,25	0,95	0,2	0,2	0,0
4	0,37	0,09	0,28	0,13	0,11	0,02	1,25	0,18	1,07	0,2	0,2	0,0
Total	1,62	0,69	0,93	1,01	0,57	0,44	5,20	1,68	3,52	1,2	1,1	0,1

loess formation from coarserly grained sediments in situ. In the steppe-zone eluvial loess formation is also recognized by BERG [2], NEUSTRUEV [14], GERASIMOV [5] and others. SERGEEV and MINERVIN [15] are of the opinion that this is the mechanism of loess formation even in the podzol-zone and they have proved their theory with model experiments. Mechanical crumbling may primarily be attributed to freezing the sample, i.e. to the process of physical weathering. At temperatures above zero, especially if moisture is sufficient, chemical weathering comes into prominence, leading to the release of sodium, calcium and magnesium. The quantities of cations released from the experimental sample and control sample are given in Table 3.

The data in Table 3 indicate the relatively considerable release of sodium. The amounts of sodium repeatedly leached from the sample subjected to freezing and heating are practically the same while in the case of the control the leached amounts of sodium steadily decrease. The amounts of released calcium and magnesium are also relatively high but no release of potassium could be observed in the course of our experiments. While the released calcium may derive from calcite, and magnesium from dolomite, sodium cannot be released but from the plagioclases which can be found in large quantities in the sample. On the basis of our previous investigations [7, 10], however, we suppose that the calcite and the dolomite were also of secondary origin, the first derived from calcium released from the plagioclases, the second from magnesium, coming from weathered chlorites or biotite, usually occurring in materials of Alpine or Carpathian origin. The sodium (and partly the calcium and the magnesium) released from the weathered plagioclases were leached by precipitation into the ground water and caused its intense mineralization.

The mineralogical composition changed as well, though it could not be unquestionably proved in such a short time. We tried to fix these changes in diffractograms (Figure 1). The appearance of hydromica (hydrobiotite?) was observed on the diffractogram both of the whole sample (prepared by spreading, dry sample orientation) and the $<0{,}001$ mm fraction, where the line kX 11,7 (Figure 2) is very marked. The quantity of finely dispersed chlorite, passing into the clay fraction, also increased.

The diffractograms of the sample after various preparations are shown in Figure 3. It may be seen that mostly illite, followed by chlorite and vermiculite, can be found in it, while montmorillonite and caolinite appear only in traces. The occurrence of dolomite and calcite in the clay fraction seems to be an indirect proof of their secondary origin in these sediments.

are of lighter texture but in the lower part of the island they are of heavier texture. (Of course there are local exceptions.) The pleistocene gravel core lies near the surface (at 1,5—2 m, but at several places only at 20—30 cm) in the upper part and it does not rise towards the other end of the island. This is schematically demonstrated in Figure 5.

The sample used in our experiment was taken in the upper part of Žitný Ostrov. Its chemical and mineralogical composition is characteristic of the sediments of that territory. As it may be seen from the horizontal cross-section of the territory, the salts, products of the weathered fragments of primary minerals, get relatively easily into the ground water, due to the favourable drainage properties of the island's gravel core. The Danubian sediments of upper Žitný Ostrov, rich in primary minerals, are considered to be one of the most probable sources of the mineralization of the ground water in this area.

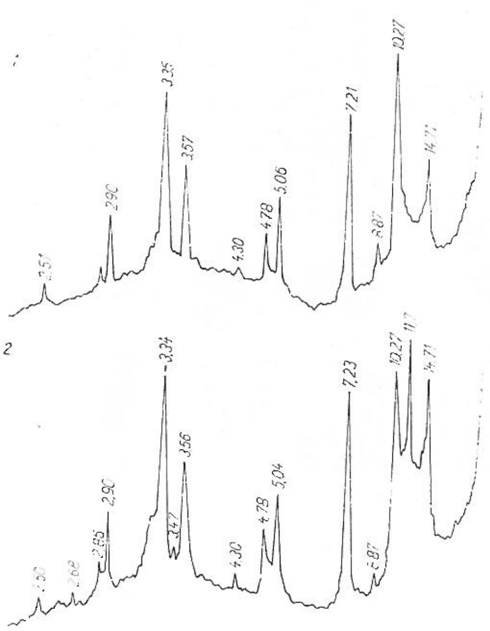

Figure 2

Diffractogram of the clay fraction ($< 1\ \mu$). 1. Clay from the original sample. 2. Clay from the sample after weathering

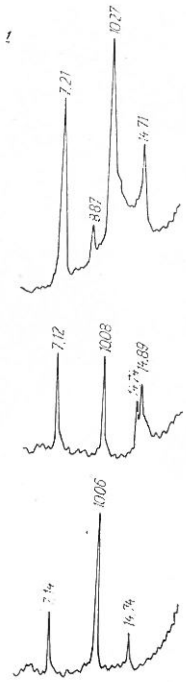

Figure 3

Diffractogram of the clay ($< 1\ \mu$) from the original sample. 1. Without preparation. 2. Saturated with glycerin. 3. Heated for 3 hours at 550°C

As it may be seen in Figure 5, the water table is situated near the surface in the lower part of Žitný Ostrov, and in certain circumstances this may lead to the formation of salt affected soils of the sodic type. As a matter of fact such soils do occur in that area.

Due to the high pH values of the soils, a part of the released calcium and magnesium precipitates in the form of calcite or dolomite in the soil profile or in the deeper layers of the deposits. This also supports our previous statement concerning the secondary enrichment of these sediments by carbonates [8]. One part of them naturally gets into the ground water and migrates with it in the form of bicarbonates and may cause the specific "salinization" of the soil profile by calcium carbonate [6, 7, 8, 9].

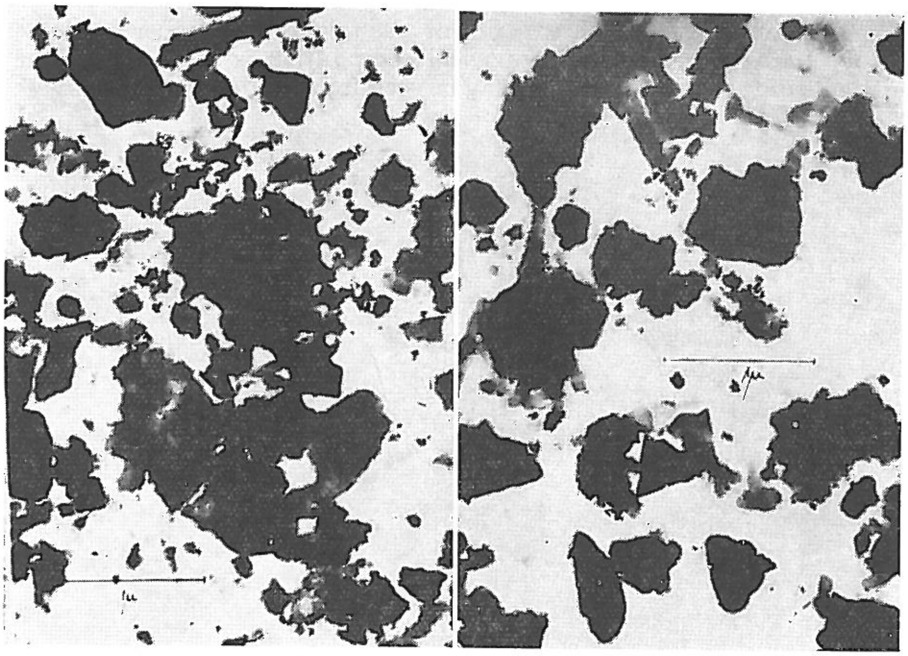

Figure 4

Electron-microscope pictures of the clay fraction. a. Clay from the original sample. b. Clay from the sample after weathering

Our experiences fully support the thesis of Darab [4] and Várallyay [16, 17] relating to the origin of salts and the formation of salt affected soils in the Hortobágy region (Hungary). Only in this particular case of ours not the weathered products of the surrounding mountain system but the already translocated sediments rich in fragments of primary rocks constitute the source of sodium.

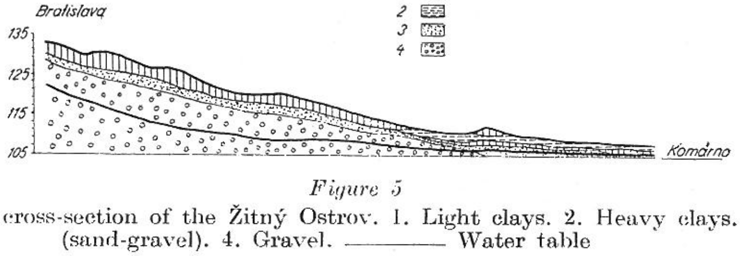

Figure 5

Horizontal cross-section of the Žitný Ostrov. 1. Light clays. 2. Heavy clays. 3. Sand (sand-gravel). 4. Gravel. ———— Water table

Summary

On studying the mineralogical composition of soils and sediments of Danubian alluviums in South Slovakia, we found that they contained considerable amounts of primary minerals. These minerals consist of mostly various feldspars with a relatively high occurrence of plagioclases, different chlorites, muscovite and biotite. In the course of our experiment a sample was subjected to artificial weathering. In the obtained aqueous extracts K^+, Na^+, Ca^{2+} and Mg^{2+} were determined.

Having concluded the experiment we analysed again the granularity of the sample.

The spread earth (without separating the fractions) was submitted to X-ray analysis by means of a diffractometer. The sample was analysed first in its original state, then after the experiment and finally after the removal of carbonates from it.

The clay minerals were also determined in the fraction smaller than 1 μ both in the experimental and control samples. Pictures of the clay fraction were taken with an electron microscope.

We ascertained that the silt content and, partially the clay content were increased in the sample. The sediment acquired the character of loess weathered in situ.

On weathering, considerable amounts of sodium, calcium and magnesium are released from the sample. They may be considered as sources enriching the soils with carbonates. One part of them gets into the ground water, causing its increased mineralization.

In our experiment we detected some changes in the mineralogical composition of the soils. The occurrence of hydromicas (hydrobiotite ?) is considered as the most significant. In our sample the clay minerals are represented mainly by illite, chlorite and vermiculite while montmorillonite and caolinite can be found only in traces. This was confirmed also by the electron microscope pictures.

In the course of our experiment it was established that the chances are great that the products of weathering get into the ground waters, migrate with them towards the lower part of the territory where they can (and actually do) cause soil salinization of the Na_2CO_3 type.

We have come to the conclusion that the sediments of upper Žitný Ostrov may be considered as one of the primary sources of sodium (and calcium or magnesium as well) causing the mineralization of the ground water in that area.

References

[1] Basilevič, N. I.: Geo-chemistry of sodic soils. (Геохимия почв содового засоления.) Izd. Nauka. Moscow. 1965. (In Russ.).

[2] Berg, L. S.: Notes on loess formation. (О происхождении лёсса) Tom. 52. Izd. Russ. Geogr. Obsc. Moscow. 1916. (In Russ.).

[3] Červenka, L.: Data on the formation of salt affected soils in southern Slovakia. (Príspevok k otázke vzniku sol'ných pôd na Južnom Slovensku.) Vedecké Prace. VÚZH 227—247. Bratislava. 1961. (In Czech.).

[4] Darab, K.: Remarks to the study by Dr. H. Franz, entitled:“ Data to the quaternary stratification and to the genesis of salt affected soils in Hortobágy and in its surroundings”. Agrokémia és Talajtan, **16.** 459—476. 1967. (In Hung.).

[5] Gerasimov, J. P.: To the questions of the formation of loess and loess-like sediments. (К вопросу о генезисе лёстов и лёссовидных отложений). Izv. Acad. Sci. SSSR. Ser. Geogr. Geofiz. No. 1. 1939. (In Russ.).

[6] Hraško, J.: Chernozems in the Danube valley. Science of the earth. (Černozeme podunajskej nížiny.) Science of the earth. Ser. Pedologica. 1. SAV Bratislava 1966. (In Czech.).

[7] Hraško, J.: The effect of water regulation on the soil conditions of Žitný Ostrov. (Vplyv vodohospodárskych úprav na pôdne pomery Žitného ostrova.) Rostlinná vyroba. No. 6. Praha. 1966. (In Czech.).

[8] Hraško, J.: Some characteristic features of the soil cover in Žitný Ostrov. Geogr. Cas. 2. 1968.

[9] Hraško, J. & Červenka, L.: Sodic soils in Czechoslovakia. Agrokémia és Talajtan. **14.** Suppl. 391—400. 1965. (In Russ.).

[10] Hraško, J., Minaříková, D. & Sajgalík, J.: The location and the properties of loess-soils in the environment of the rivers in the lowland. (Zloženie a vlastnosti spraší úkolí vel'kych nízniyych riek.) Vedecké Prace. Laboratória pôdoznalectva. No. 3. Bratislava. 1968. (In Czech.).

[11] Lehký, M. & Gyalokay, M.: Drainage in Žitný Ostrov. (Režim spodných vôd Žitného ostrova. (Hydrologická studia. VUV. Bratislava. 1964. (In Czech.).

[12] Ložek, V.: Report on the results of investigations concerned with the microzoology of Žitný Ostrov. 1953. (Zpráva o malakozoologickem výskumu velkého Žitného ostrova v roce 1953. Prace II. sekcie. SAV Bratislava. 1955. (In Czech.).

[13] Lukniš, M. & Mazúr, E.: Geomorphological districts of Žitný Ostrov. (Geomorfologické regióny Žitného ostrova.) Geomorficky časopis No. 3. 1959. (In Czech.).

[14] Neustruev, S. S.: Theory of loess formation. (Почвенная теория лёссообразования) Priroda. No. 1—3. 1925. (In Russ.).

[15] Sergeev, E. N. & Minervin, A. V.: The essence of afforestation in the podzol-zone. (Сущность процесса облёссования в подзолистой зоне) Vestn. Moskov. Univ. No. 3. 3—14. 1960. (In Russ.).

[16] Várallyay, Gy.: Salt accumulation processes in soil of the Danube valley. Agrokémia és Talajtan. **16.** 327—356. 1967. (In Hung.).

[17] Várallyay, Gy.: Questionable statement in the study by Dr. H. Franz entitled: "Data to the quaternary stratification and to the genesis of salt affected soils in Hortobágy and in its surroundings". Agrokémia és Talajtan. **16.** 448—458. 1967. (In Hung.).