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MINERAL SEQUENCE ON SOME Pb + Zn ORE DEPOSITS OF TURKEY

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ABSTRACT

The paper contains a description of mutual sequence relations among the main minerals on some Turkish lead-zinc deposits, based on megascopic and microscopic observation of samples. The described deposits are ordered in the sense of the author's paragenetic classification as mineral associations A to G. Following localities have been studied: Murgul, Nefsishakköy, Kirnoba, Şihman-Mercan, Aksu near Muradin, Ağizlar, Harami, Kurnaköy, Muradin (Sisorta), Su Alti near Muradin, Çakiroba, Altinoluk, Kerakoca, Keban Maden, and Sarikeler Ocaği near Pozanti. Some more complicated mineral sequence schemas are shown also in the Tables from I to V.

During the period 1968—1970, the author has visited numerous polymetallic deposits in Turkey collecting the samples for his paragenetic research of isogenetic Pb + Zn mineral associations incl. the geochemical character of galena, sphalerite and tetrahedrite [1]. The amount of samples of some deposits allowed him to study also the mineral sequence. The result of the research based on a combination of the megascopic observation of handspecimens and of the microscopic study is submitted in the present paper.

When compared with some older data concerning the mineral sequence in the corresponding deposits, the author found often numerous generations of the common minerals such as quartz, pyrite, hematite, and even chalcopyrite. This characteristic feature is typical for almost all subvolcanic deposits not only in Turkey but is valid generally. On the other hand, the worker is aware that some accessory minerals lacking in his mineral sequence tables could be found after a longer research on deposits but cannot change the general character of the tables.

The studied localities are ordered in the sense of the paragenetic system of Turkish Pb + Zn deposits by BERNARD [1].

Association A — pyrite + Cu + Zn ± Pb association of stockworks and of younger epigenetic mineralizations on volcano-sedimentary or hydrothermal-sedimentary pyrite deposits, bound on Upper Cretaceous to Early Tertiary dacito-rhyodacite volcanism, in the northern zone of the eastern Pontids.

Murgul, Artvin vilayet

The ores are deposited in intensively altered dacites or rhyodacites* and tuffs in the form of stockworks composed of veinlets, silica rich impregnations and irregular mass. Main ore components are pyrite and chalcopyrite, the FeS_2: Cu ratio is, however, here much more favorable then on Cu poor pyrite deposits of the Lahanos type. Pyrite is present in numerous generations, represented mainly by strikingly

* Oral communication of. Ing. R. STOJANOV, Skopje.

big crystals (up to 3 cm) in form of combination of pentagonal dodekahedrons with the octahedron or even pure octahedron crystals belonging to the oldest generation. Chalcopyrite is mostly present in the form of impregnations and irregular mass; sphalerite forms veinlets (maximally 3—4 cm thick) often impregnated by chalcopyrite. Megascopically its colour seems to be black but in smaller grains a dark green-brown colour is visible. In cavities fine crystals of tetrahedral or triakistetra-

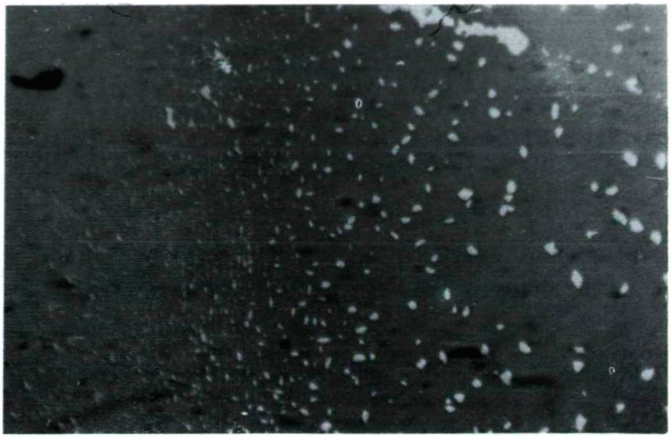


Fig. 1. Ex-solution structure of chalcopyrite in sphalerite from Murgul, Artvin vilayet. Magn. 160 x

hedral type can often be found. Galena is mostly found in impregnation as granular aggregate, tennantite (with predominance of As over Sb) and bornite form thin veinlets or massive aggregates in the altered country rock. Quartz (often as amethyst), barite and carbonates form crystalline aggregates, in cavities often very fine crystals of common habit are found.

TABLE I.

Mineral sequence on the ore deposit Murgul, Artvin vilayet

Mineral sequence:

WIJKERSLOOTH [8] published the following mineral sequence:

1st phase: magnetite (hematite)-pyrite-chalcopyrite-quartz,

2nd phase: chalcopyrite-bornite-sphalerite-galena-quartz,

3rd phase: tetrahedrite-yellow brown sphalerite-ankerite-barite.

Later SCHNEIDERHÖHN [7] described a simple sequence schema: pseudomorphous quartz + pyrite; clear quartz + chalcopyrite, galena, tetrahedrite, sphalerite, pyrite; clear quartz + hematite.

According to my field and microscopic research, the following sequence of main mineral components of the deposit was esteblished (Table 1):

1st mineralization period: The oldest hydrothermal component is represented by a mass of fine-grained quartz *I* impregnating altered country rocks and containing big crystals of pyrite *I*; pyrite crystals are often weathered out of the rock. The best locality for such pyrite crystals is in the upper level of the western section of the open mine (situation as of Summer 1969). Quartz *I* mainly of the upper zone is often formed as brick-red fine-grained variety pigmented by hematite and described as carneol [7].

2nd mineralization period: After intensive tectonic movements causing the brecciation of the altered country rock and minerals of the 1st mineralization period, a new portion of hydrothermal solution has ascended and has given the origin of quartz *II* with some ores. This mostly colourless or white crystalline or crystallized quartz contains the pyrite *II* in form of small irregular grains or crystals and the main mass of chalcopyrite. The mineralization of the both early periods represents the absolute majority of all hydrothermal products on the deposit.

3rd mineralization period: Locally in cavities, the radiated aggregates of quartz *III* (amethyst) have crystallized. This striking vein filling is afterwards cut by veinlet system of younger minerals. Among them the oldest is pyrite *III* as fine—grained aggregate, then chalcopyrite *II* in big grains and massive textures. It is often associated with granular sphalerite containing another chalcopyrite generation *(III)* as very fine-grained oriented inclusions representing a product of a complex solution; they can be even partly interpreted as real ex-solutions from the solid solution ZnS — $CuFeS_2$.

Quartz *IV* as the next member of the sequence is only in microscopic amounts. It forms metacrysts on boundaries between sphalerite and chalcopyrite *III*. Younger is pyrite *IV* as groups of grains of crystals cutting the mass of sphalerite and crystals of quartz *IV*. The next minerals are tennantite and galena the mutual sequence position of which cannot be determined due to their non-simultaneous occurrence. Galena forms granular filling of veinlets cutting sphalerite and older minerals. Tennantite found even in bigger mass is mostly fine-grained and penetrates the sulphidic filling; its relation to pyrite *IV* is unknown. In cavities and druses the crystals of previously described sulfides are covered by small druse of colourless quartz *V*.

4th mineralization period: Monomineral barite mineralization cuts all previous hydrothermal products in veinlets or forms very fine tabular crystals up to 3 cm big in cavities.

5th mineralization period: This period has an almost carbonatic character. It is represented mainly by siderite as granular aggregate in veinlets or, in cavities, as fine lenticular crystals often covered by younger white columnar crystals of calcite. Less common is ankerite and dolomite which form young filling together with siderite or a cement in the breccia with fragments of older minerals incl. barite.

Later the secondary minerals such as limonite, Cu-carbonates etc. originated. Many other rarer minerals can be expected on the deposit but their discovery needs more detailed field research.

From the neighbouring deposit *Kuvarshane, Artvin vilayet,* WIJKERSLOOTH [8] has described the mineralization in three periods (phases):

1st period — quartz, pyrite and chalcopyrite (+ some sphalerite),

2nd period of polymetallic character with younger generation of chalcopyrite,

3rd period — calcite.

According to my observation also tennantite and barite are the characteristic accessories in Kuvarshane.

Nefsishakköy (Batlama), Giresun vilayet

In the studied material the main components are black sphalerite and chalcopyrite with some pyrite and a microscopic amount of tennantite and barite. Quartz is the main gangue mineral. All named minerals cement fragments of the altered dacitic country rock.

Sphalerite seems to be here the oldest of observed sulfides. It is penetrated by other named minerals in veinlets or groups of grains in the following sequence: quartz—pyrite—chalcopyrite—tennantite.

Association B — Pb + Zn + Cu association of ore veins in the effusive rocks and tuffs bound on plutonic and subvolcanic magmatism in the northern zone of the eastern Pontids.

Kirnoba, Gümüshane vilayet

The samples show complicated textures, mainly with ore minerals. The mineral sequence is as follows:

1st mineralization period: As the oldest mineral has been determined the quartz *I* in fine-grained aggregate penetrating the country rock.

2nd mineralization period: The main ore filling is formed by brown sphalerite aggregate; on its surface in cavities and even on walls of the partly brecciated sphalerite aggregate sit many pentagonal-dodekahedral crystals and grains of pyrite *I* forming often bigger accumulations in ore veins.

3rd mineralization period: This is the main ore period. After an intensive brecciation of the older mass, tetrahedrite (with dominance of Sb over As) cemented the breccia so that the fragments of sphalerite and pyrite *I* seem to flow in tetrahedrite. Chalcopyrite in small amount penetrates in veinlets the mass and is younger than tetrahedrite. Later, after another brecciation, quartz *II* with very fine-grained pyrite cement the older mass, the quartz *II* often forming fine metacrysts towards the older sulfides. The last important ore mineral is the granular galena.

4th mineralization period: After a brecciation a coarse—grained barite aggregate of brown-yellowish colour penetrates the mass.

5th mineralization period: Cutting all previous ore vein fillings, ankerite is the last primary mineral.

KIEFT [4] found here the following sequence: pyrite—sphalerite—chalcopyrite and tetrahedrite—galena.

Sihman—Mercan, Ordu vilayet

Intensively whitened andesite and tuffs are penetrated by a system of veins formed by light grey quartz containing big grains of galena, green-brown sphalerite, chalcopyrite, and pyrite. The sulphides sequence is as follows: pyrite — chalcopyrite *I* in massive aggregates — sphalerite with chalcopyrite *II* inclusions — galena.

Afterwards was the sulfide filling brecciated and cemented by very abundant druse of younger white quartz *II* with numerous crystals. The last hypogene mineral is the brown ankerite in crystals covering quartz *II* crystals in cavities.

Aksu near Muradin, Ordu vilayet

Galena, dark yellow-green sphalerite and some chalcopyrite form big metacrysts in a fine-grained calcite-dolomite aggregate of hydrothermal origin cementing altered clastic effusive country rock. Younger ankerite in veinlets with common druse cuts and the partly brecciated sulphides.

Ağizlar, Gölköy ilce, Ordu vilayet

Altered andesite contains narrow ore veins with polymetallic mineralization formed mainly by quartz and sulphides. A yellow-green or yellow-brown sphalerite predominates together with galena. The general mineral sequence is as follows:

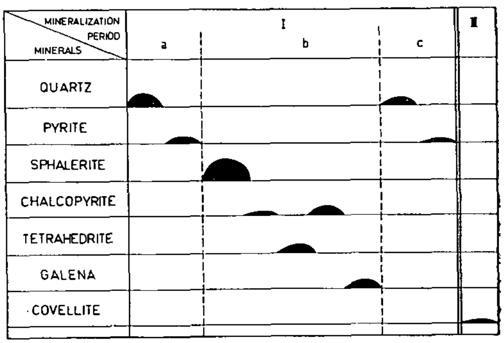
1st mineralization period contains the main ore minerals and quartz *I* which is the oldest component. The ores crystallize in the following sequence: pyrite *I* — sphalerite with partial overlapping with the younger chalcopyrite — tetrahedrite — galena. At the end of the first period a younger generation of quartz and pyrite *(II)* originated.

2nd mineralization period is monomineral and belongs to a pinkish Mn-calcite cementing the older minerals. The locality has been studied in detail by Mr. Ayhan Erler, M. S., as a part of his M. S. thesis at METU, Ankara.

Harami, Kabadüz district, Ordu vilayet (Table II)

Intensively altered country rocks are cut by ore veins with a banded structure. Some bands are composed only by the oldest fine-grained grey quartz with some

Table II.



Mineral sequence on the ore deposit Harami, Kabadüz district, Ordu vilayet

pyrite, some contain cavities and are filled by big grains of yellow to dark yellow—green sphalerite with some chalcopyrite *I* inclusions and by tetrahedrite, chalcopyrite *II* and galena. In druses the crystals of the named minerals occur. The youngest primary component is quartz *II* in big white individuals with small pyrite grains. Covellite is abundant in the cementation textures.

Kurnaköy, Ordu vilayet

In the ore vein filling from the mine of Őmer Şenses, a grey fine-grained quartz contains a very coarse-grained dark yellow-brown sphalerite with fine triakistetrahedral crystals in cavities. Younger are the less common crystals of galena, later tabular crystals of barite, and at the last — simple rhombohedrons of calcite occur.

Association C — Pb + Zn + Cu association of hydrothermal deposits bound on the Tertiary volcanism or granitoids of the southern zone of the eastern Pontids and of western Pontids.

Muradin (Sisorta), Ordu vilayet

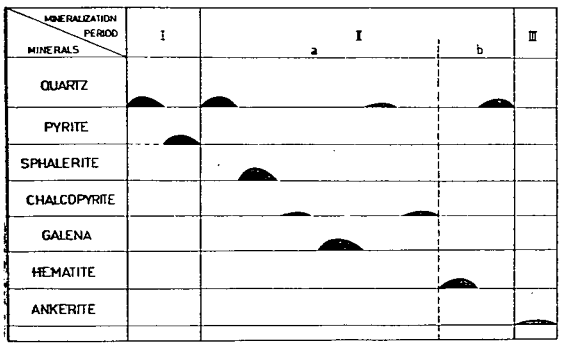
Grey-green chloritised country rock contains vein and veinlets mineralization; its predominant texture is a brecciated one, the banded texture is mostly only of short continuation.

Mineral sequence (Table III):

1st mineralization period: As the oldest components the impregnating quartz *I* with pyrite *I* occur, pyrite often being in the from of crystals in combination of cube and pentagonal-dodekahedral forms.

2nd mineralization period: After another brecciation a new portion of quartz *(II)* as white or colourless druse originated. The cavities of the druse are filled with a granular aggregate of brown to yellowish brown sphalerite, less chal-

TABLE III.



Mineral sequence on the ore deposit Muradin (Sisorta) Ordu vilayet

copyrite *I*, and common galena. The origin of minerals of this period is closed by crystallization of quartz *III* druse with fine bisphenoidal crystals of chalcopyrite *II* in the cavities. Hematite as scally specularite and the younger quartz *IV* form many bands or impregnation in the sulfide mineral aggregate.

3rd mineralization period is represented by ankerite with smaller amount of yellowish or less common white calcite.

Then originated many different secondary minerals such as cerussite, green secondary Cu minerals etc.

A detailed description of the mineral sequence from Muradin has also been submitted by ILAVSKÝ—GRENÁR [3] who found partly different sequence of some minerals and, in addition, also traces of tetrahedrite and other Cu sulfides.

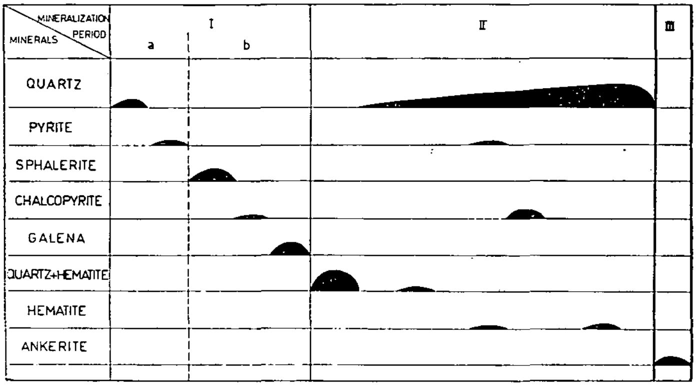
Su Alti near Muradin, Ordu vilayet

For Su Alti mineralization a characteristic sign is the rhythmic structure of the younger portion of the ore vein filling. In some sections quartz-hematite bands predominate, in other sections they alternate with granular mass of galena or sphalerite.

Mineral sequence (Table *IV*):

1st mineralization period: It is composed of quartz and the main ore minerals. Quartz *I* and pyrite *I* impregnate the altered country rock in a fine aggregate or they form the central part of the brecciated sulfide mass.

TABLE IV.



Mineral sequence on the ore deposit Su Alti near Muradin, Ordu Vilayet

Then the subperiod of the main ore mineral components crystallized with brown to yellow-brown coarse-grained sphalerite with some chalcopyrite. Galena is often very coarse-grained and its aggregate is mostly fragmented.

2nd mineralization period: As the oldest seems to be the fine-grained aggregate of quartz and of scally hematite-specularite of a dark red colour. This

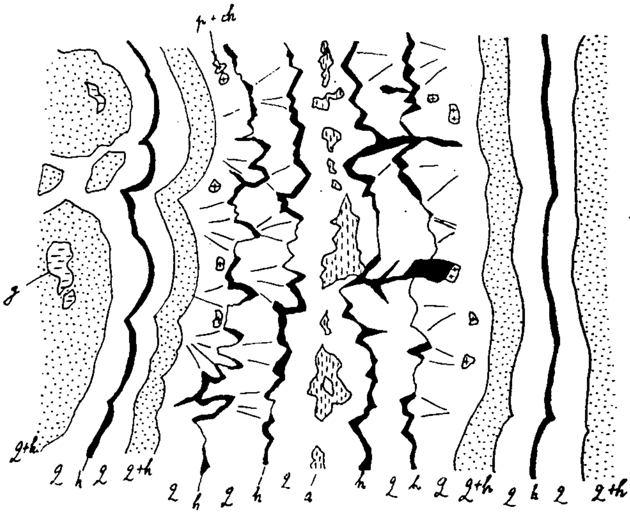


Fig. 2. A characteristic banded rhythmic structure from Su Alti near Muradin, Ordu vilayet. Quartz *(q)* and hematite *(h)* are younger then the polymetallic filling, represented here by galena *(g)* and then most of the quartz+hematite fine-grained aggregate. Pyrite and chalcopyrite are present in one quartz band, ankerite *(a)* fills the youngest geodes

aggregate is mixed with the minerals of the first period. Later, better defined banded zones of rhythmically segregated quartz and hematite originated; their thickness changes from one to another zone (between 1—10 mm mainly). The number of rhythmical banded zones varies from one place to another, the most often case is the case expressed in the enclosed table: white quartz druse — quartz + hematite — white quartz covered on crystal top by black tabules of specularite — white quartz often with crystals in cavities.

3rd mineralization period is represented by yellow-brown fine-grained ankerite cutting all the older filling and cementing its fragments.

Cakiroba, Edremit ilce, Balikesir vilayet

The main ore vein filling is formed by fine-grained white quartz *I* containing small grains of galena, yellow-brown sphalerite, and small grains of chalcopyrite and pyrite. As the youngest of named minerals seems to be galena forming small simple crystals toward the cavities. The origin of the vein filling is closed by quartz *II* in drusy aggregates, covered by small white calcite crystals.

Altinoluk, Edremit ilce, Balikesir vilayet

A fine-grained brownish quartz *I* cementing remnants of brecciated altered rocks includes the aggregate of the yellow—brown sphalerite, galena, and pyrite. Younger is the white quartz *II* as banded drusy aggregate with younger greyish calcite crystals. Another filling of these druses belongs to the product of oxidation: small crystals of cerussite, yellow pyromorphite, skeletons of smithsonite, limonite, and malachite.

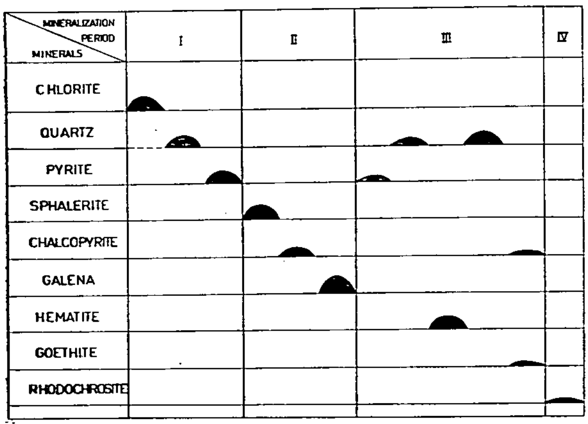
Association D — Pb + Zn + Cu association of ore veins or hydrothermal components of contact skarns in the contact zones of granitoids of Anatolids and western Pontids.

Karakoca, Simav ilce, Kütahya vilayet

Granitic rock altered by propylitization is along the dislocations mineralized by polymetallic ores with gangue in banded or brecciated structures.

Mineral sequence (Table V):

TABLE V.



Mineral sequence on the ore deposit Karakoca, Simav ilce, Kütahya vilayet

1st mineralization period: The oldest vein components are the dark-green chlorite, quartz *I*, and pyrite *I* impregnating the country rock or forming the oldest bands in the vein filling.

2nd mineralization period: It is composed mainly of ore minerals. The oldest is brown sphalerite with some inclusions of chalcopyrite which with some doubt may be parallelized with the massive chalcopyrite *I* of the ore vein filling. Galena is the youngest mineral of the period. All of them form granular or banded aggregates.

3rd mineralization period: In bands, in cavities of as breccia cementation material are the following minerals: pyrite *II* in smaller crystals or in grains together with quartz *II* and hematite as specularite scales. Characteristic younger components of the 3rd mineralization period are represented by quartz *III*, often as amethyst, with some chalcopyrite *II* in small grains or rather fine crystals of bisphenoidal type. Some groups of yellowish-brown long columnar aggregates of goethite with visible cleavage along (010) planes have been observed here too; due to its sequence position goethite may be considered a hypogene mineral.

4th mineralization period: Carbonates occur here in small amount, mainly as pink rhombohedrons of rhodochrosite sitting on the quartz *III* druse.

Association E — Pb + Zn + Cu association of ore veins or ore bodies in the areas around the intrusive massifs of Taurids.

Keban Maden, Elâziğ vilayet

In the ore bodies filling on the main deposit Derebaca, a black crystalline sphalerite predominates over pyrite and galena. Pyrite *I* in form of brecciated grains cemented by sphalerite and galena has been observed as the oldest component. Younger is the second generation of pyrite with some marcasite in colloidal textures penetrating the older mass mainly sphalerite. As the youngest is to be considered the light brown ankerite and white calcite in veinlets cutting all older mineral filling.

A similar mineral sequence was mentioned by MAUCHER [1937, in GEOFFROY, 2]. KOVENKO [6] found on the main deposit Derebaca the following sequence of ore minerals: pyrite — löllingite — sphalerite *I* (Fe-rich) — chalcopyrite — sphalerite *II* (very rich in Fe 47%?) — As tetrahedrite (or rather tennantite) — jordanite — proustite — marcasite. To the last members may belong also very rare bournonite and jamesonite and newly discovered polybasite [5]. One of main ore components — galena — is lacking in the KOVENKO's sequence by obvious mistake.

In the same area in Kebandere a different scarce high-temperated polymetallic association occurs with magnetite, hematite, pyrrhotite and fluorite besides chalcopyrite, galena, sphalerite and Fe sulphides [6].

Sarikeler Ocaği near Pozanti, Adana vilayet

The brecciated filling of ore vein is formed mainly by coarse—grained black sphalerite with a greenish tint.

Mineral sequence:

1st mineralization period: Fine-grained quartz *I* with pyrite *I*.

2nd mineralization period: Crystallization of the dark-green to black sphalerite with many fine chalcopyrite inclusions took place; in its outer zone toward the cavities accumulate galena and chalcopyrite *II* as younger minerals.

3rd mineralization period: Quartz *II* together with grains of pyrite *II* forms veinlets cutting the older mass or is present as a filling of druse with imperfect crystals of sphalerite or galena.

4th mineralization period: After a distinct brecciation of the filling the pale-brown fine-grained ankerite cements the older mineral components.

The mineral sequence was not studied on deposits of association F and G of Taurids, resp. Iranids.

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THE MINERAL COMPOSITION OF HUNGARIAN SOILS II. SOILS OF THE BALATON REGION

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ABSTRACT

About 30 soil samples of the Balaton region (Hungary) have been investigated; all for their granulometric composition, 24 full chemical analyses were made and in 24 the mineral percentages have been determined by the diffractometer. The geographical position and the geological conditions are also sketched. — The method of determination gives also the amorphous (and poorly crystallized) content, the chemical and mineralogical composition of which has been evaluated on plausible assumptions.

In the preceeding communication of this series [1] we displayed the general points of view and purposes of our researches. Now the granulometric composition, the chemical and mineralogical composition of numerous soils from different regions of Hungary have been determined. We give in the following the results of our work on soils of the Balaton region.

I. SOILS OF BALATON-SZABADI

a) Geographical position

The cooperative "November 7" of B.-Szabadi lies along the southeastern shores of the Lake Balaton (German: Plattensee). Following the natural geography it belongs in part to Mezőföld and in part to the hilly land adherent to the Balaton. The greater part of the region lies on the comb of Enying in Mezőföld. This region is genetically and geologically much better known, than Zala County.

b) Geological conditions

The comb of Enying stretches from B.-Aliga as far as the juncture of the river Sió and the rivulet Kabóka. One has a good view of the complete section of the comb from the high banks of the Balaton near B-.Aliga where in the vertical or nearly vertical walls the upright layers show a horizontal direction. A study of these high walls — with the allowance of the eventual pinch out — reveals also the geological structure of the inner territories lying farther from the lake.

The northern part of the comb of Enying as far as the rivulet Kabóka is composed of very different layers. We find sandy and loamy layers with lignite seams alternating in thickness. The southern part of the comb, the region sinking toward the Sió is built of typical loess. One can draw the border between the two layers in the second third of the area between B.-Aliga and B.-Világos. SE of the high bank the loess sometimes reaches a substantial depth (10—15 m), since it has not been exposed to erosion as much as it was in the vicinity of the bank.