GEOLOGY AND MINERAL DEPOSITS OF THE HOPA-MURGUL REGION (WESTERN PART OF THE PROVINCE OF ARTVİN, NE TURKEY)

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INTRODUCTION

Geological investigations of the western part of the province of Artvin were carried out by geologists Z. Barut, Dr. C. Kahrer, Dr. L. Klay, Dr. A. Kraeff, Dr. H. Potter and Dr. H. Zankl under supervision of Dr. G. van der Kaaden during the summer period of 1959.

The following areas were mapped on a scale 1 : 42,000 :

1. Hopa region by A. Kraeff;
2. Western-central part of region by Z. Barut and H. Potter;
3. Southwestern part of Murgul area by L. Klay;
4. Southeastern part of Murgul area by C. Kahrer;
5. Northeastern part of Murgul area and adjacent Çoruh region by H. Zankl.

The author had the possibility to visit several parts of this region. In order to put on record a complete synthesis of the geology of the whole region, the author is presenting a compilation of the works of the above-mentioned geologists.

The rock samples were microscopically investigated by Dr. G. van der Kaaden and the author.

This geological investigation was important because it threw a new light on the geology, tectonics and mineralization of this region. The geological studies prove the block-faulting character of this region and illuminate the different phases of magmatic activity and mineralization. This region belongs to the eastern Pontides, which have a germanotype structure.

I. GEOLOGIC STRUCTURE OF THE HOPA-MURGUL REGION

(Plate I; Figs. 1, 2, 3)

Rock formations in this region can be subdivided from old to young into :

11. Alluvial-Pleistocene deposits.
10. Late-Tertiary basalts and aridesites.
9. Albite tonalites, albite granodiorites and albite granites of Tertiary age.

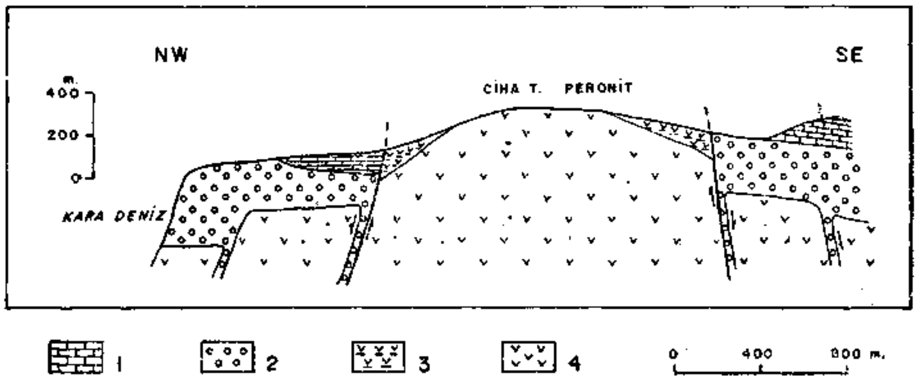


Fig. 1 - NW-SE section of the Hopa region (Section D)
(After A. Kraëff)

1 - Limestone-marl series; 2 - Spilitic series II; 3 - Dacitic tuffs; 4 - Albite dacite I.

8. Albite dacites III.
7. Tuff series (Upper Gampanian-Eocene ?).
6. Limestone-marl series (Upper Campanian-Eocene ?).
5. Hippuritic limestone series (Turonian-Lower Campanian).
4. Spilitic series II.
3. Albite dacites II.
2. Albite dacites I.
1. Spilitic series I.

1. *Spilitic series I.*— Spilitic series I is only outcropping in the area of Murgani hevi D. and Scutari D. It consists of natron-keratophyre spilites with tuffs and agglomerates. In the adjacent southern area G. Kahrer found that these spilites were impregnated sometimes with pyrite.

2. *Albite dacites I with their tuffs.*— Albite dacites I, which have an average thickness of 500 m, are outcropping in the northwestern part of the region, viz. Peronit-Abano-Sivrikaya area, and in the Murgul region, viz. southern Murgul area, eastern Murgul area with adjacent Çoruh area.

Albite dacites, partly silicified albite dacites, totally silicified albite dacites and dacitic tuffs are distinguished.

The unaltered albite dacites which are occurring e. g. in the northwestern part of the region (Peronit-Abano area and Ciha Tepe-Peronit area) are characterized by quartz phenocrysts and albite phenocrysts lying in a quartz-bearing groundmass which may contain laths of albite. Partly and totally silicified albite dacites are outcropping in the northwestern part of the region and in the southern and eastern parts of the Murgul area. The partly silicified albite dacites show clearly idiomorphic quartz phenocrysts and silicified or sericitized plagioclase phenocrysts lying in a totally silicified groundmass, which is always a little sericitized.

Totally silicified albite dacites consist of a mosaic of xenomorphic quartz crystals, which are bordered by small sericite flakes. The dacitic tuffs are mostly also silicified.

These albite dacites I are the locus of some important chalcopyrite-sphalerite, and pyrite deposits (viz. in Murgul, Akarşen, Kuvarshan, Sinkot, Irsa, Peronit-Abano, Sivrikaya). Concerning the description of these mineral deposits reader is referred to chapter III.

Anticipating the description of those mineral deposits it is worth to mention, that albite dacites I contain two systems of fractures, viz. extending in NW-SE or N-S directions and in NE-SW or W-E directions. The mineralizations favored the weakest places of the silicified albite dacites I, viz. the intersections of these fractures. Silicification and mineralization (in the genetical sequence : quartz-pyrite-chalcopyrite-sphalerite-tetraedrite-galena) are the result of hydrothermal action of further differentiated acid magma.

3. Albite dacites II.— Albite dacites II are outcropping in the northwestern part of the region, viz. in Ciha Tepe, Arhavi and their vicinity and in the vicinity of Murgul Maden. They are somewhat younger than albite dacites I. Albite dacites II are coarse-grained, mostly unaltered and greenish in color. Sometimes in the vicinity of ore deposits they show red-violet colors due to dissemination of iron oxydes. Sometimes xenolites of spilitic series I are enclosed in albite dacites II. They are partly intrusive or extrusive.

In the vicinity of Murgul Maden albite dacites II are locally covering dacitic tuffs or albite dacites I. At certain places, where albite dacites II are covering albite dacites I, a clear erosion disconformity is established. Albite dacites II are not mineralized.

4. Spilitic series II.— Spilitic series II is outcropping in the northwestern part of the region (Hopa-Arhavi area), in the southeastern, northeastern part of the Murgul area and in the Çoruh area. Locally this series may be 1000 meters thick.

In spilitic series II also a fracture system running in N-S, NW-SE and W-E, NE-SW directions is developed.

This spilitic series consists of spilites, natron-keratophyre spilites, spilitic agglomerates and spilitic tuffs. They contain sometimes locally inclusions of reddish dacite II and of red limestones.

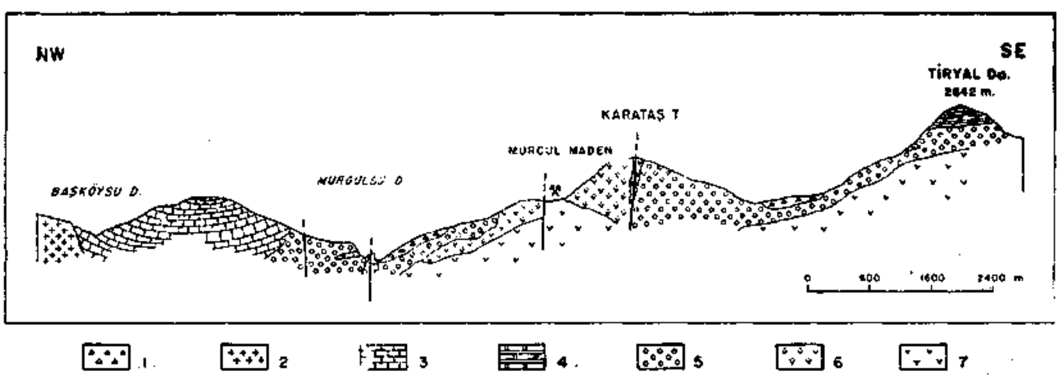


Fig. 2 - NW-SE section of the Murgul area (Section E)
(After L. Kläy)

1 - Debris and landslide masses; 2 - Albite tonalite; 3 - Limestone-marl series; 4 - Hippuritic limestone series; 5 - Spilitic series II; 6 - Albite dacite II; 7 - Albite dacite I.

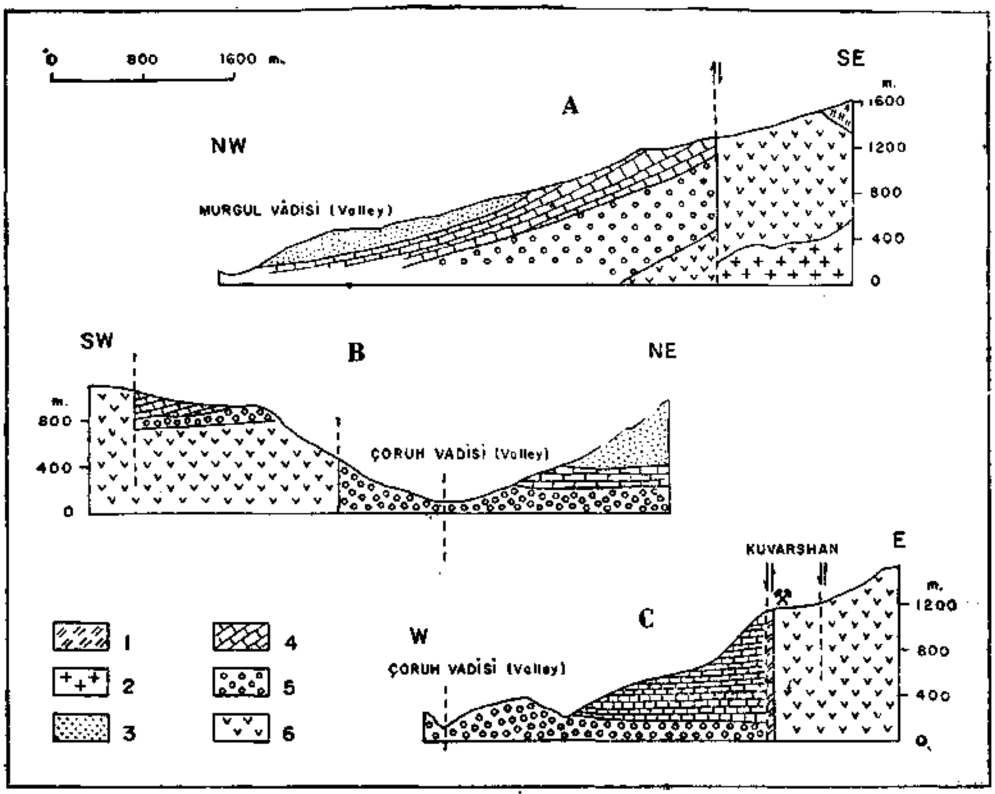


Fig. 3 - Sections A-B-C of the Çoruh region
(After H. Zankl)

1 - Andesite; 2 - Granodiorite; 3 - Tuff series; 4 - Limestone-marl series; 5 - Spilitic series II; 6 - Albite dacite I.

In the northwestern part of the region, along the road Kise-Peronit, thin 2 m thick Radiolaria-bearing limestone beds are intercalated in this spilitic series, indicating a submarine origin.

The spilites and natron-keratophyre spilites are macroscopically characterized by dark green-brown green colors and by typical pillow structure in which the lava exhibits the appearance of a pile of small masses which can be compared to pillows, bolsters, sacks and cushions. Further they contain veins of zeolite and calcite.

The characteristic feature of these extrusive rocks is the occurrence of albite as phenocrysts and as laths in the groundmass. Spilites and natron-keratophyre spilites might be considered as amygdaloidal albite basalts or as albite diabases. The difference between spilites and natron-keratophyre spilites is that the former contain augite, which is lacking in the latter.

The spilites have an intersertal texture : albite laths form a framework so arranged that polygonal interspaces are left between the crystals; these interspaces are filled with augite and sometimes with glass and ore grains. Numerous amygdaloidal vesicles occur which are filled with chlorite, calcite and zeolite. The natron-keratophyre spilites consist of albite laths, with glass and chlorite in the interstices, forming an intersertal texture. Numerous amygdaloidal cavities occur, which are filled with calcite, chlorite, quartz and zeolite.

The spilitic rocks north of Kuledibi (Hopa area) contain some small manganese ore deposits.

5. Hippuritic limestone series (Turonian - Lower Campanian). — The Hippuritic limestone series is outcropping locally south of Petek, in the vicinity of Akarşen, at Tiryal Tepe and their northeastern vicinities. This series is dipping into northern direction.

Lithologically they consist of reddish layered limestones and of beds of white massive limestone.

These limestones are rich in macro- and microfauna.

Their macrofauna contains Hippurites, Brachiopoda, Corals, Echinoderma and Bryozoa. The microfauna contains Radiolaria and Foraminifera *(Globotruncana lapparenti lapparenti, Globotruncana lapparenti tricarinata)*. This microfauna, determined by A.C. van Ginkel, proves the Turonian-Lower Campanian age.

Between the Hippuritic limestone series and the younger limestone-marl series an unconformity exists.

6. Limestone-marl series (Upper Campanian-Maestrichtian-Eocene?). — This series consists of limestones, marly limestones, marls, sandstones and tuffs. At some places in the Murgul area this limestone-marl formation is separated unconformably by a transgression conglomerate from the underlying Hippuritic limestone series.

This limestone-marl series forms a large curved zone, extending from the vicinity of Hopa till the vicinity of Murgul and can be followed east of the Murgul area till the Çoruh area. This curved zone broadly outlines the strike pattern of this series.

The strike of the formation in the Hopa area is NE-SW with SE dips, it changes in the vicinity of Pilarket into NW-SE direction with mostly NE dips and bends from there into NE-SW direction with NW dips, till Başköy. From Başköy the strike bends again from the NE-SW direction with NW dips to the NW-SE direction with NE dips of the Çoruh area. The dip angle is varying between 5° and 55° ; the average dip angle is about 25°. The age of this limestone-marl series is proved as Upper Campanian-Maestrichtian by microfauna, as determined by A.C. van Ginkel *(Globotruncana* cf. *sluarti, Globotruncana* cf. *conica, Globotruncana* cf. *rosetta)*.

The upper parts of this series in the vicinity of Kuvarshan are extending into Eocene. V. Kovenko (1942) described here a rich microfauna consisting of Nummulites, Assilines, Globorotalias and *Miscellanea miscella* d'Arch.

The thickness of this series is variable; in the western part the thickness is about 500 m and in the northeastern Murgul area the thickness is outwedging from 100 m till some meters in the vicinity of the Çoruh River. In southeastern direction, viz. in the vicinity of Kuvarshan it increases again till 500 m.

The sandstones south of Kuledibi contain stone-quarries. These sandstones are used for the construction of houses and as road material.

7. *Tuff series* (Upper Campanian-Maestrichtian-Eocene?). —- The tuff series is outcropping in the central part between Hopa and Murgul area, and further in the northeastern part of the Murgul area and in the Çoruh area.

This series consists of tuffs, tuffites, agglomerates and natron-keratophyre dykes. It covers partly the underlying limestone-marl series. It is younger as the underlying limestone-marl series and belongs perhaps to a geological period which extends from Upper Campanian-Maestrichtian till Eocene.

These three sedimentary formations (Hippuritic limestone series, limestone-marl series, tuff series) show, as the older geologic units, a fracture system running in N-S, NW-SE and in W-E, NE-SW directions.

8- Post-Cretaceous albite dacites III. — Albite dacites III are outcropping south of Kuledibi, in the vicinity of Karmatkale Tepe, NE of Başköy, in the vicinity of Operlemet and in the Gölbaşı area.

Only albite dacites III of the Operlemet area and of Gölbaşı contain some unimportant pyrite and other sulphidic mineralizations.

9. Albite tonalites, albite granodiorites and albite granites of Tertiary age. — Acid plutonic rocks are outcropping near Kise, Başköy and along the Kokoletsu Dere.

Albite tonalite of Kise is intruded partly in the spilitic series II and partly in the limestone-marl series. It is holocrystalline and consists of numerous hypidiomorphic albites and of a little quartz intergrown with albite in vermicular forms (myrmekite). Dark minerals include a little hornblende, augite, chlorite and ore grains. In Kokoletsu Dere albite tonalites, albite granodiorites and albite granites are intruded in albite dacites I. At their contacts some unimportant pyrite impregnations are developed.

The albite tonalites of Başköy are intruded in the limestone-marl series.

10. Late-Tertiary andesites and basalts.— Late-Tertiary andesites and basalts are outcropping in the central part of the region, viz. in Dagest Dağ, Ralişki Tepe and in some places between the Murgul and Çoruh area.

They are intruded along fracture zones and are extruded partly on top of the older geologic units.

Among andesites : hornblende andesites, augite andesites, hornblende-augite andesites, olivine-augite andesites are distinguished.

Among basalts : augite basalts, augite-hornblende basalts, olivine basalts and augite-olivine basalts are distinguished.

As an exception some of these andesites and basalts are more or less albitized.

11. *Alluvial-Pleistocene deposits and debris deposits.*— The lower course of the Hopa River consists of Alluvial-Pleistocene deposits.

Southeast of Murgul large debris and landslide masses are covering partly the subsurface.

II. TECTONICS AND MAGMATIC CYCLES

As stated previously, these geological investigations proved the block-faulting character of the Hopa-Murgul region. This germanotype (horsts and grabens) structure was also confirmed by other geologists in other parts of the eastern Pontides; viz. Zankl (1961) in Harşit Valley, Schultze-Westrum (1961) in Giresun-Aksudere region and Kraeff (1963) in Sirya-Ardanuç region.

In connection with the geology of the adjacent Sirya-Ardanuç region (east of Artvin) the first taphrogenetic (=block-faulting) movements occurred in a period before the formation of spilitic series I. These movements continued then during every younger geologic period and gave rise to horsts and grabens, which are typical for the whole eastern Pontides.

All geologic units of the Hopa-Murgul region demonstrate a fracture pattern consisting of two fault directions; viz. N-S, NW-SE direction and W-E, NE-SW direction.

These large fractures have facilitated the intrusions of igneous rocks and formed channelways for the mineralizations. In the NW part of the region (Hopa area and central area), NW-SE and SW-NE faults are predominating, whereas in the Murgul area and Çoruh area, N-S and W-E faults are more frequent. Especially in the Çoruh area the grabens form a chess-board structural pattern.

Concerning this horst and graben structure very illustrative examples can be studied in the NW-SE section of the Hopa area (Fig. 1) and in the sections of the Çoruh area (Fig. 3).

In general, the N-S faults were oldest, while the W-E faults were somewhat younger. The mineralizations favored the weakest places and are therefore located especially in the intersections of these fractures.

As in the Sirya-Ardanuç region, the magmatic cycles play an important part in the geologic history of this region.

The first magmatic cycle is here absent, because Paleozoic albite granodiorites are only occurring in the Sirya-Ardanuç region.

The second magmatic cycle is here characterized by basic and acid differentiations. To the basic differentiation products belong spilites I, to the acid differentiation products belong albite dacites I, their tuffs and the albite dacites II.

The silicification of albite dacites I and their mineralization can be considered as hydrothermal action of the further differentiated acid magma of the 2nd cycle.

The third magmatic cycle is characterized first by pre-Upper Cretaceous basic differentiation products (spilites II) and later by post-Eocene acid differentiation products (albite dacites III, Tertiary albite tonalites, albite granodiorites and albite granites).

The Hippuritic limestone series, limestone-marl series and tuff series are formed between the basic and the acid differentiation products of the 3rd magmatic cycle.

Characteristic for the 3rd magmatic cycle, especially for its acid differentiation is the very insignificant mineralization, which is due to hydrothermal action of the further differentiated acid magma.

The fourth magmatic cycle is only characterized by basic differentiation products : andesites and basalts, and partly albitized andesites and basalts.

All igneous rocks of the 2nd, 3rd, 4th magmatic cycles (except some extrusiva of the 4th magmatic cycle) belong to a kindred characterized by relative abundance of soda which results in albite being the typical felspar.

In the following schedule these above-mentioned facts are summarized :

Tectonics	*Igneous rocks*	*Magmatic events*	*Sediments*
TAPHROGENESIS	Basalts, andesites	Basic differentiation (4th magmatic cycle)	
	Very small mineralization	Hydrothermal action of further differentiated acid magma	
	Albite tonalite, albite granodiorite, albite granite Albite dacite III	Acid differentiation (3rd magmatic cycle)	
			Tuff series (Upper Cretaceous-Eocene)
			Limestone-marl series (Upper Cretaceous - Eocene)
			Hippuritic limestone series (Upper Cretaceous)
	Spilitic series II	Basic differentiation (3rd magmatic cycle)	
	Albite dacite II	Acid differentiation (2nd magmatic cycle)	
	Silicified albite dacite I + silicified tuffs; pyrite-chalcopyrite-sphalerite	Silicification, mineralization (Hydrothermal action of further differentiated acid magma)	
	Albite dacite I + tuffs	Acid differentiation (2nd magmatic cycle)	
	Spilitic series I	Basic differentiation (2nd magmatic cycle)	

III. MINERAL DEPOSITS

In this article the author distinguishes between copper-pyrite-zinc-bearing ore deposits associated with albite dacites I and the manganese ore deposits associated with dacitic tuffs or spilites.

The insignificant pyrite deposits of Operlemet and Gölbaşı, which are associated with albite dacites III, are not described here.

A. Chalcopyrite-pyrite and sphalerite-bearing deposits

As mentioned before, the copper-pyrite-and zinc-bearing ore deposits occur in the vicinities of intersections of N-S/NW-SE, and W-E/NE-SW fracture lines in silicifled albite dacites I.

The following chronological picture shows in general :

1. Silicification and partly kaolinization of some parts of albite dacites I and their tuffs.

2. Mineralization (in the genetical sequence: pyrite-chalcopyrite-sphalerite - tetraedrite-galena-sphalerite) of special fracture zones of the silicified albite dacites I. The mineralization favored the weakest places of silicified albite dacites I, viz. the intersection of N-S/NW-SE and W-E/NE-SW fracture lines.

This silicification and mineralization is caused by hydrothermal action of further differentiated acid magma of the 2nd magmatic cycle.

The following copper-pyrite and zinc-bearing ore deposits are here described, viz. :

1. Sphalerite-chalcopyrite deposits of Peronit-Abano.
2. Pyrite deposits of Sivrikaya and their vicinities.
3. Copper ore deposits of Murgul.
4. Copper-bearing pyrite deposits of Akarşen.
5. Copper ore deposits of Kuvarshan.

1. Sphalerite and chalcopyrite deposits of Peronit-Abano (Fig. 4). — The sphalerite and chalcopyrite deposit of Peronit-Abano is situated halfway the road Arhavi-Hopa.

Several small pyritized faults running in NW-SE and NE-SW directions are here observed.

In the northern part of the silicified albite dacites I of the Peronit-Abano area are driven two tunnels at two levels in the vicinity of ancient Genoese workings. These tunnels were driven in the period before the First World War and are collapsed since 1936.

According to the investigations of von Struve made in 1902, these two tunnels contain several hydrothermal veins rich in sphalerite, galena and copper ore.

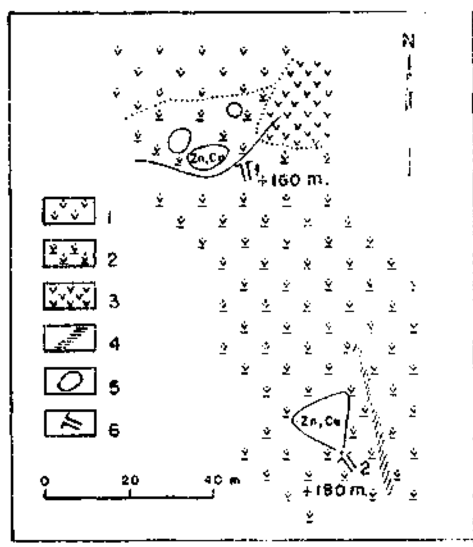


Fig. 4 - Sketch-map of Peronit - Abano
(After A. Kraëff)

1 - Partly silicified albite dacite I; 2 - Totally silicified albite dacite I; 3 - Albite dacite I; 4 - Kaolin zone; 5 - Zn, Cu dump; 6 - Tunnel.

These crosscuts intersected a chalcopyrite vein of 0.50-0.80 m thickness and a vein of 1.70 m thickness dipping into eastern direction at 70° and consisting of sphalerite, galena and copper ores.

The ores sampled on the dumps of these two tunnels consist of:

a. Numerous blocks of sphalerite. Sphalerite is intergrown with and contains inclusions of tetraedrite, galena, pyrite, chalcopyrite, covellite and bornite.
b. Subordinate blocks of pyrite and chalcopyrite.
c. Subordinate blocks of silicified albite dacites rich in brecciated pyrite and accessory chalcopyrite.
d. Subordinate blocks of silicified albite dacites rich in pyrite and accessory sphalerite, galena, covellite and chalcopyrite.

The general impression of the ore dumps is predomination of sphalerite in regard to copper ores.

This hydrothermal mineralization is limited to small localities and has little economical importance.

2. Pyrite deposits of Sivrikaya and their vicinities (Fig. 5). — In the vicinity of Sivrikaya, at a distance of approximately 1.5 km SW of Peronit - Abano, are outcropping two silicified albite dacitic breccias, rich in pyrite.

A military road constructed in the period of the First World War has cut these silicified albite dacites I of Sivrikaya and Hulusi Tepe and two pyrite-rich ore bodies of a brecciated structure were discovered.

The northern silicified albite dacitic breccia of Hulusi Tepe, rich in pyrite, shows an outcrop extending in NW-SE direction of about 1.60 m length a height of 1.40 m and a fracture extending in N-S direction.

The silicified breccia contains numerous 1-5 mm wide veins of quartz and pyrite.

The southern silicified albite dacitic breccia of Sivrikaya, rich in pyrite, shows an outcrop extending in W-E direction, of about 30 m length, 5 m height, and two faults extending in NE-SW direction. This silicified breccia rich in pyrite is covered by a silicified zone without pyrite.

These gray-colored silicified breccias contain numerous 1-5 mm wide veins of quartz and pyrite (Fig. 5-A). Sometimes they contain veins of barite with quartz. The pyrite, 1-2 mm in diameter, is mostly idiomorphic. Sometimes a single accessory grain of chalcopyrite and traces of covellite are observed.

At a distance of about 250 m WSW of Sivrikaya are located some small collapsed exploration tunnels in silicified albite dacites I of the valley of Sivrikırmağı. According to von Liew, who visited these tunnels during the period of the First World War, they contain only very narrow veins of chalcopyrite. On a dump some blocks of chalcopyrite and of sphalerite-bearing pyrite are left.

From economical point of view these above-mentioned mineralizations are of little importance.

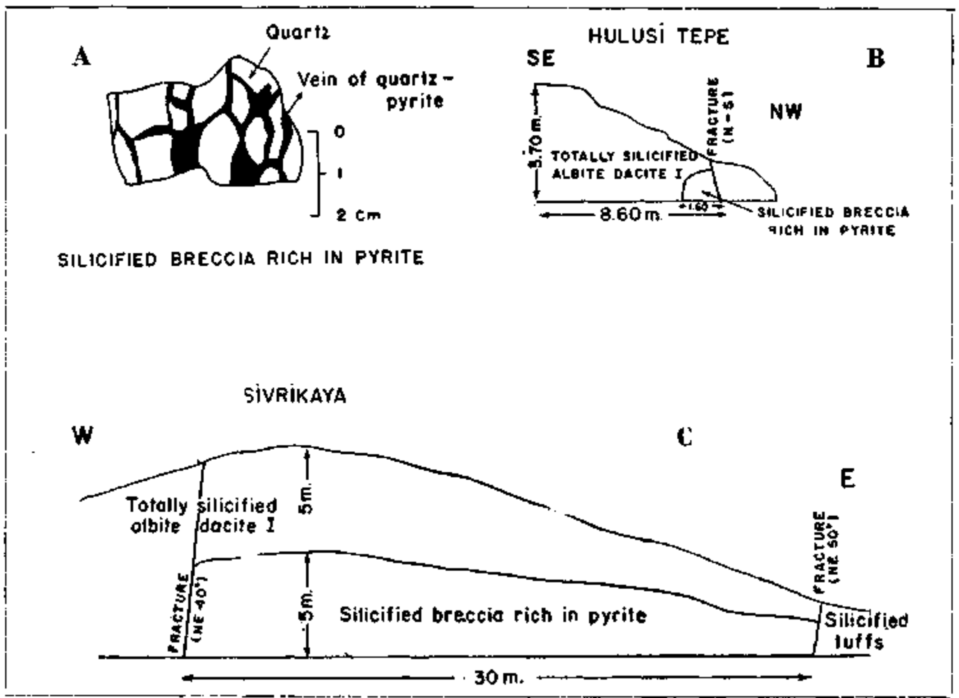


Fig. 5 - Silicified breccias rich in pyrite in the vicinities of Sivrikaya and Hulûsi Tepe
(After A. Kraëff)

3. Copper ore deposits of Murgul. — The well-known copper ore deposits of Murgul are located at a distance of about 3 km SE of Murgul.

The oldest mining activities are of medieval (Genoese) time.

Since the year 1898 the first systematic exploration was carried out. In 1900 the Caucasus Copper Company was established and produced during the period 1907-1914 16,000 tons of copper.

After the peace treaty of Lausanne in 1923 this area was reunited with Turkey. The first activities of Etibank began in 1938.

Regular production started in 1951 after the establishing of a concentration plant and smeltery. The copper ore reserves of the Murgul open-cut mine are estimated at 16 million tons of copper ore with an average grade of 2.08 % Cu. Mining rare is currently 1200 tons per day and blister output 21 tons a day. The blister assays 0.39 oz Au and 28.29 oz Ag/ton.

From 1958-1962 M.T.A. and Etibank discovered, south of Murgul mine around Çakmakkaya, by drillings in silicified albite dacites I, an ore reserve of approximately 20.8 million tons assaying 1.08 % Cu.

The Murgul mine consists of three ore bodies, viz. Çangara-, Sosweni-, and Satep ore bodies. The dimensions of the Çangara-Sosweni ore body on level + 1150 m are 450x300 m. The thickness is about 100 m. Below this level the copper content is lower than 0.8 %, but the mineralization continues. The copper ore deposits are associated with silicified albite dacites I.

Very instructive is the NW-SE section of the Murgul area, according to L. Klay (Fig. 2). Silicified albite dacites I, which are partly covered by silicified tuffs, are locally overlain by reddish albite dacites II. The mineralization is limited to silicified albite dacites I. Between silicified albite dacites I and younger reddish albite dacites II, locally a thin bed of kaolin of about 10-20 cm thickness is developed.

The totally silicified albite dacites I of Murgul consist of brecciated quartz masses containing numerous veins and veinlets of pyrite and chalcopyrite. The thickness of these ore veins varies between some millimeters till 10 cm. Besides pyrite and chalcopyrite some accessory sphalerite, tetraedrite and galena occur as small inclusions in chalcopyrite.

Secondary mineralization consisting of bornite, rhombic chalcosite, covellite and lamellar chalcopyrite is concentrated in a thin cementation zone in the upper parts of the deposit, but most of it has been exploited. Also some malachite and azurite occur.

This silicified albite dacitic region of Murgul contains a fracture system consisting of two fault directions, viz. W-E faults and NW-SE faults.

The mineralization (in the genetical sequence: pyrite-chalcopyrite-sphalerite-tetraedrite-galena-sphalerite) favored the weakest places of the silicified albite dacites I, viz. the intersections of the above-mentioned fault lines.

The silicification and mineralization of the albite dacites I is due to hydrothermal action of further differentiated acid magma of the 2nd magmatic cycle.

4. Copper-bearing pyrite deposits of Akarşen.— These deposits are located at a distance of about 7 km SW of Murgul. During the period 1912-1913 the Siemens Company made some exploration drillings. Later, Etibank estimated this ore reserve at 30,000 tons assaying 3.5% Cu.

Geologic investigations of this region are difficult because of dense vegetation and therefore not every detail is cleared up.

According to investigations of L. Klay in 1959, the mineralization of the copper-bearing pyrite ore is situated in the upper parts of silicified albite dacites I, which are partly covered by spilites, marls, limestones and tuffs of Upper Cretaceous age.

This complex ore consists of pyrite, chalcopyrite, sphalerite and tetraedrite. The average copper percentage is varying between 3 and 5%. This complex ore assays 3.5-338 gr Ag/t. and 0.25-7.2 gr Au/t. The copper-rich pyrite upper level strikes ESE and dips steeply NNE. It could be traced over a distance of 170 m, with a width of 20 m and a slant height of 30 m. The ore reserves are estimated at 300.000 tons assaying 3-5% Cu.

The copper-poor pyrite mineralization belongs to a lower part of the silicified albite dacites I. Possible reserves of the copper-poor pyritic ore are estimated at 3-4 million tons.

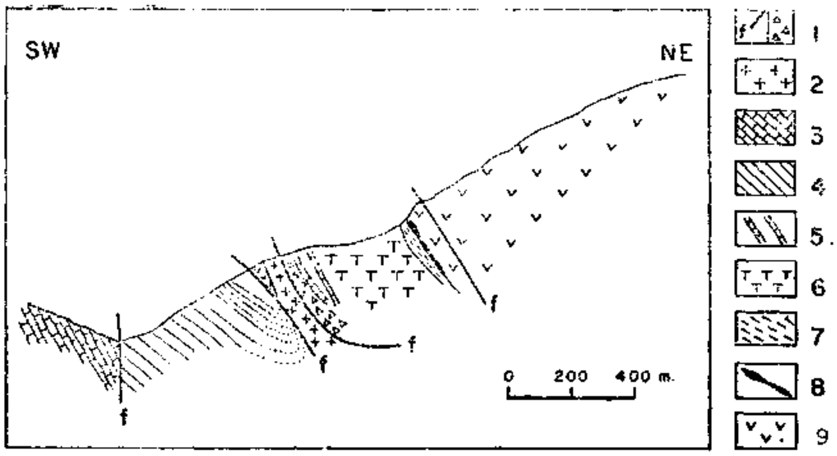


Fig. 6 - Kuvarshan section SW-NE (Section F)
(After V. Kovenko, corrected by H. Zankl)

1 - Fault zones/tectonic breccia; 2 - Hornblende andesite; 3 - Limestone-marl series (Upper Cretaceous); 4 - Limestone-marl series (Eocene); 5 - Limestones intercalated in spilites; 6 - Spilitic series II; 7 - Tuffs and limestones; 8 - Copper deposits; 9 - Silicified albite dacite I.

5. Copper ore deposits of Kuvarshan.— The copper ore deposit of Kuvarshan is located in the eastern Çoruh region. This deposit was studied by V. Kovenko (1941) and by P. de Wijkerslooth (1946). H. Zankl reinvestigated in 1959 this area and has given a modern interpretation concerning the geology of the area. The region of Kuvarshan is situated eastwards of the large N-S fault line of the eastern Çoruh region.

Very instructive is the SW-'NE section of the Kuvarshan region, which originally was compiled by V. Kovenko (1941) and later reinterpreted by H. Zankl (Fig. 6).

In this region two fault directions, viz. the NW-SE and the NE-SW faults arc developed. Only the NW-SE fault zones are important for the mineralization. After studying the geology of this region (compare SW-NE section of Kuvarshan, Fig. 6), it becomes clear that the. Kuvarshan deposit is situated in an overturned block zone. The Kuvarshan section demonstrates a reversed succession of rock beds: limestone beds, spilitic series, ore lenses, silicified albite dacites I. By reversible motion of the block, the normal succession of rock beds, which is typical for the Hopa-Murgul region, is shown.

Some years ago the mine was in production. During the period 1937-1941 8,800 tons of metallic copper was produced. At this time the mine is closed. The mineralization is associated with silicified albite dacites I. According to P.de Wijkerslooth (1946), who made an elaborate study concerning this mineralization, this mineral deposit strikes NW-SE and dips NE with an angle of 70°-80°. The deposit has an irregular lens-shapedl form. Its striking length is about 250 m, slant height is about 250 m and the greatest thickness 25 m. The hanging wall of this deposit consists of silicified albite dacites I and the foot wall consists of marbles and spilites.

P. de Wijkerslooth (1946) distinguishes between two types of mineralization, viz. the upper part consisting of copper-poor pyritic ore (Gelberze) and the lower part which is more rich in copper (Grauerze).

The «Gelberze» consists of pyrite, chalcopyrite and accessory galena. This ore assays .1-1.5 % Cu.

The «Grauerze» consists of chalcopyrite, bornite, neodigenite, chalcocite, sphalerite, accessory galena and tennantite. This ore assays 6-7 % Cu. The adjacent mineral deposit of Irsa, situated at a distance of 3 km north of Kuvarshan mine, is located eastwards of the same important N-S fault zone of the eastern Çoruh region.

The Irsa deposit forms a horst consisting of silicified albite dacites I, which are partly overlain by spilites II. It is a small mineral deposit and assays 2-4 % Cu and 15-25 % Zn.

The other adjacent mineral deposit of Sinkot is situated at a distance of 3 km SW of Kuvarshan. Some years ago, an exploration tunnel was driven in the silicified albite dacites I which intersected massive pyrite ore. This pyrite ore is poor in copper. It assays maximum 0.9 % Cu.

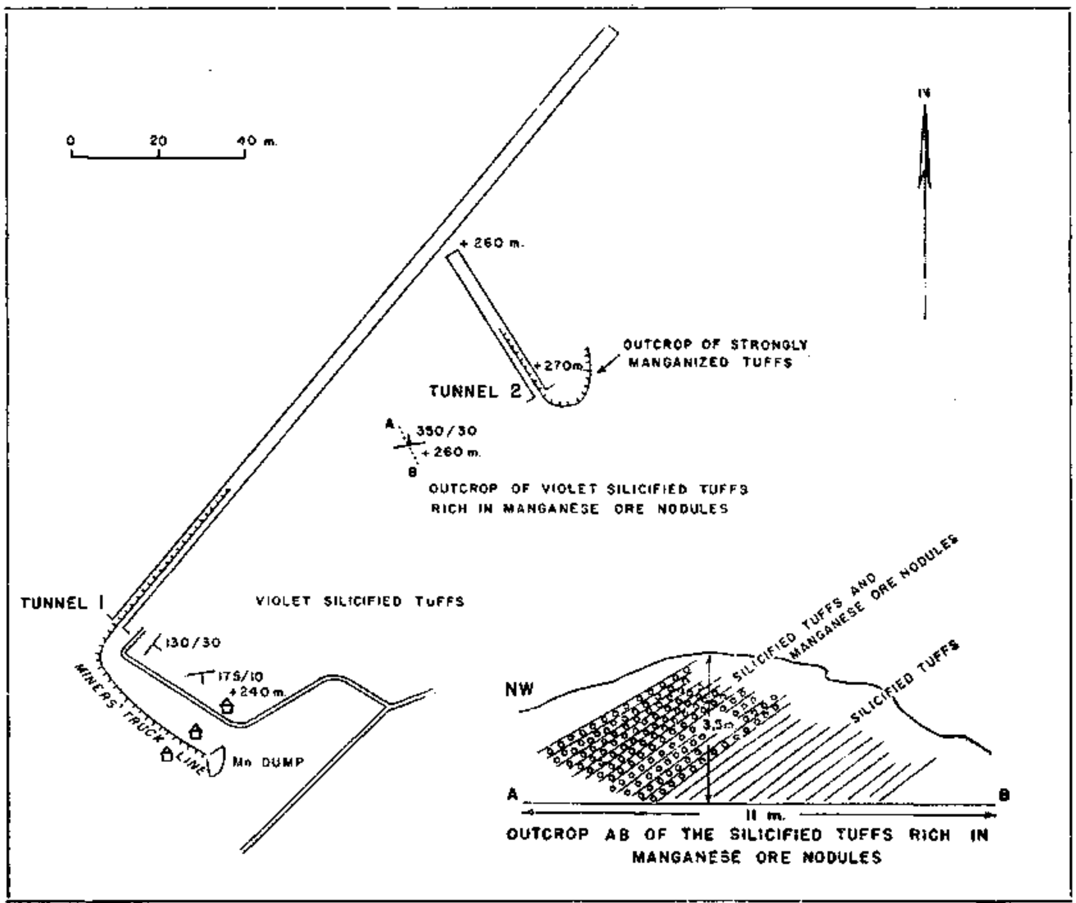
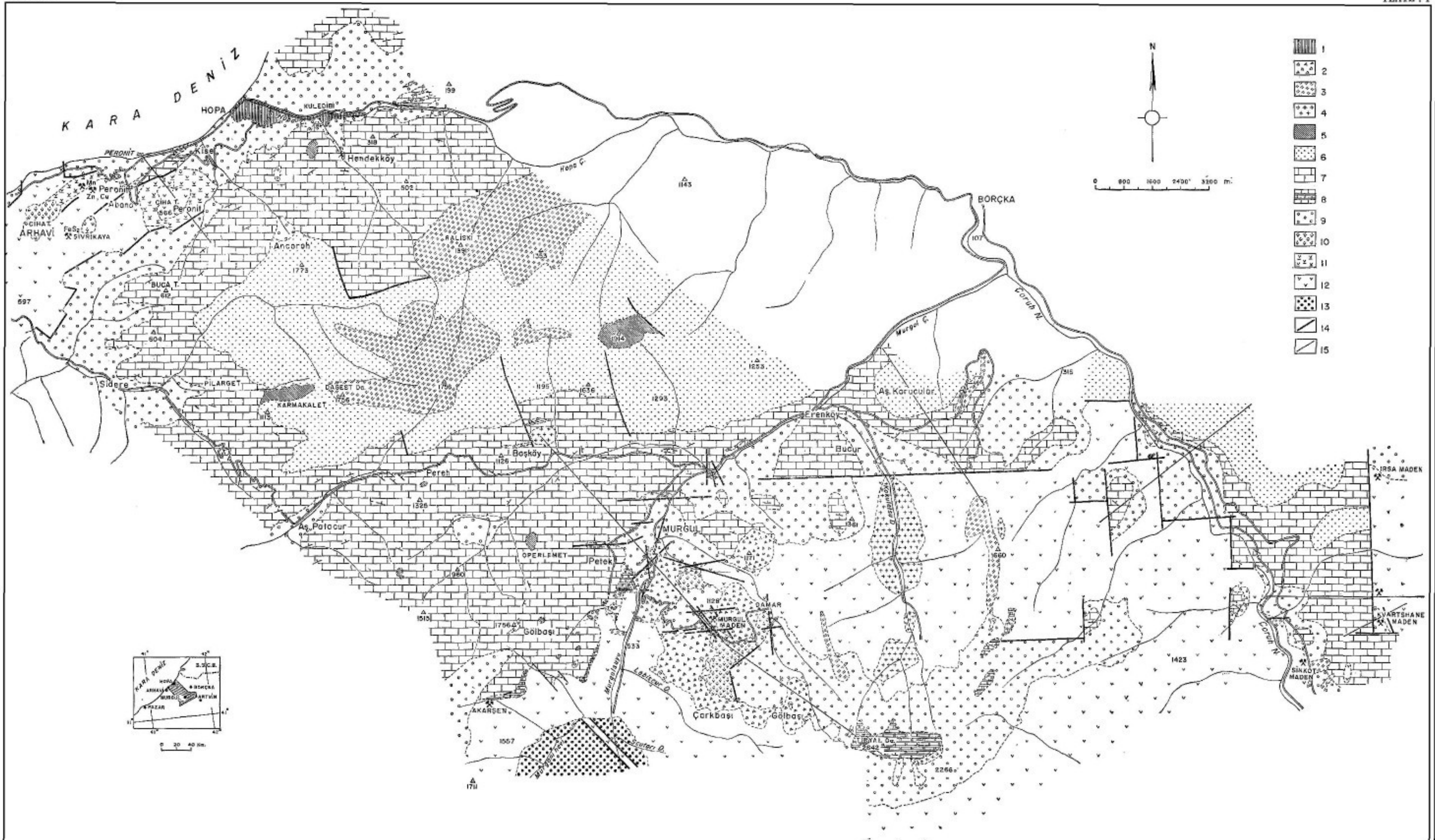


Fig. 7 - Map of the manganese mine of Peronit

(After A. Kraëff)



GEOLOGIC MAP OF THE HOPA-MURGUL REGION

BY

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1 - Alluvial Pleistocene deposits; 2 - Debris and landslide masses; 3 - Late Tertiary basalts, andesites; 4 - Tertiary albite tonalites, albite granodiorites, albite granites; 5 - Albite dacites III; 6 - Tuff series (Upper Campanian-Eocene?); 7 - Limestone-marl series (Upper Campanian-Eocene?); 8 - Hippuritic limestone series (Turonian-Lower Campanian); 9 - Spilitic series II; 10 - Albite dacites II; 11 - Dacitic tuffs; 12 - Albite dacites I; 13 - Spilitic series I; 14 - Fault line; 15 - Section line.

B. Manganese ore deposits

Manganese ore deposits of Hopa-Murgul region can be divided in :

1. Manganese ore deposits associated with dacitic tuffs;
2. Manganese ore deposits associated with spilites.

1. Manganese ore deposits associated with dacitic tuffs (Fig. 7).— To this type belongs the manganese ore deposit of Peronit. The manganese mine of Peronit is located along a small jeep road at a distance of about 2.5 km SW of the small village of Peronit.

The yearly production of this mine was about 2000 tons of manganese ore with an average of 48 % Mn.

The mine contains two tunnels, viz. tunnel 1, 180 m long and nearly horizontal and tunnel 2, 40 m long and 10° inclined.

At the present time the mine is out of production.

The manganese oxide ores are located in violet-colored silicified dacitic tuffs. These tuffs belong to the acid differentiation products of the 2nd magmatic cycle.

The manganese ores consist of pyrolusite, polianite and accessory opal-chalcedony, assaying 53.62 % Mn, 8.68 % SiO_2 and 0.05 % P.

At a distance of 80 m NE from the entrance of tunnel 1, an outcrop (compare section A-B of Fig. 7) 11 m long and 3.5 m wide shows layered violet-colored silicified tuffs dipping NW at 30°. The upper part of these silicified tuffs contains small manganese ore nodules (1-2 cm in diameter). An other outcrop, at a distance of 40 m NE from this above-mentioned outcrop, consists of strongly manganiferous dark brown-violet colored silicified tuffs.

The manganese ores of Peronit are considered as the products of submarine exhalations belonging to the 2nd magmatic cycle.

2. Manganese ore deposits associated with spilites.— Several small unimportant manganese ore deposits occur in spilitic rocks of the Murgul region. Also a small unimportant manganese ore deposit occurs in the spilitic series II of Kuledibi (Hopa region).

The manganese ore of Kuledibi consists of pyrolusite and siliceous material. It assays 33.34 % Mn, 27.89 % SiO_2 and 0.02 % P.

The genesis of the manganese ores is probably due to volatile fraction of the basic magma (belonging to the basic differentiation of the 3rd. magmatic cycle) which was shed into sea water.

Manuscript received January 18, 1963

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