NEW EVIDENCE ON THE ORIGIN OF THE CHIATURA MANGANESE DEPOSIT

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The Chiatura manganese deposit is widely known as a typically sedimentary deposit with large reserves of high quality ores, concentrated within a limited area.

The ores belong mainly to the three following types: *1)* primary oxides, *2)* carbonates, *3)* oxidized ores. Carbonate ores are reported from the central part of the deposit, whereas primary oxides occur in its peripheral parts.

Host rocks of the deposit are represented by opokas and spongiolites. The thick beds of bentonitic clays and clinoptilolite, revealed in the Upper Oligocene cover of the ores by the recentmost lithologic studies, suggest some volcanic ash supply to the Upper Oligocene sedimentation basin [MACHABELI *et al.*]. Quantity and grain-size of the terrigenous detritus, composing the Oligocene arcosic sandstones, increases eastward. In the eastern margin of the deposit a thick sequence of the Lower Oligocene clays and sandstones contains only few thin ore-bearing beds, but is increasingly enriched in ore-bodies towards the west and gradually displaced by the latter, so that in the western periphery of the deposit the Upper Cretaceous limestones are directly overlain by primary oxide ores, containing but an insignificant admixture of terrigenous material.

A. G. BETEKHTIN who was first to study the Chiatura deposit in detail, suggested that manganese, as well as arcosic detritus, was derived from the Paleozoic granitoids, presently exposed in vicinity of the deposit. But A. G. BETEKHTIN disregarded that manganese content of these granites is below clark (0,04%). Besides, his concept failed to explain a rapid accumulation of manganese within a comparatively short period of the Lower Oligocene; whereas weathering of granites (predominantly mechanical) proceeded during a long interval of time.

In our search for manganese source of the Chiatura deposit we came to the conclusion that manganese could be supplied only by hydrothermal solutions, that were very active in the late Upper Eocene — early Oligocene, i. e. in postvolcanic stage of an intense Paleogene volcanism of the Adjaro-Thrialethian geosyncline [DZOTSENIDZE, 1965]. The assumption was based on the neighbouring position of the Chiatura deposit to the Adjaro-Thrialethian folded system. The well known theorist of climatic types of lithogenesis N. M. STRAKHOV agrees with the present author, that granites were unable to provide the quantity of manganese accumulated in the Chiatura Oligocene basin. But he considers the Middle Jurassic spilitic series, spread north of Chiatura as a possible source of manganese, referring to the fact that manganese content of the Middle Jurassic volcanics approaches clark value (0,1%) and occasionally attains 0,4—0,5% [DZOTSENIDZE, 1948]. In this connection we would like to point out that as far as no products of the Middle Jurassic volcanic series are present in the terrigenous rocks of the Chiatura deposit, it is rather difficult to accept this series as the possible source of manganese. Certainly, this fact should not be neglected. Besides, nobody even attempts to explain how it is possible that manganese derived from magmatic rocks during long processes of weathering and deposition accumulated in few thick ore-beds instead of being evenly distribute throughout the sedimentary sequence along with other products of weathering.

In last years new data were obtained, strongly supporting volcanic-sedimentary origin of the Chiatura and adjacent deposits. Most important among these are the results of the study of the Kvirila depression deposit, located WSW of Chiatura *(Fig. 1)*.

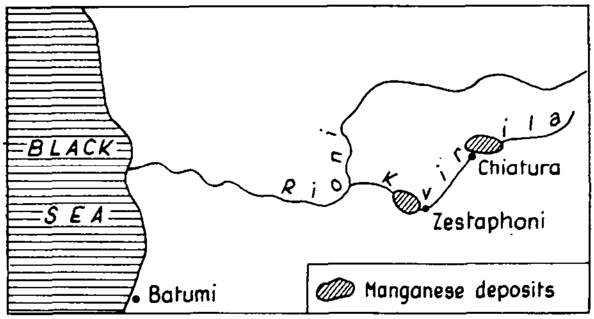

Fig. 1

Being quite similar in their general upbild, the Chiatura and Kvirila depression deposits differ by their geological setting. What are the similarities? First, either deposits occur in the Oligocene strata and are apparently closely correlative in age. Second, the section of the ore-bearing sequence in both deposits is much alike. In the Kvirila depression as in Chiatura host rocks are opokas, spongiolites, glauconitic rocks. Here, too, the ores are represented by primary oxides, carbonates and oxidized varieties. But in the Kvirila depression dominate clays of so called Maikopian type, and among them the above-named rocks form lenses of various dimensions.

The principal distinction between the Chiatura and Kvirila depression deposits is their different geological position.

The Chiatura depression is located in the elevated part of the Georgian median block, called the Dzirula mass. The latter is composed of Paleozoic granitoids, crystalline schists and quartz-porphyries. In the Lower Liassic a significant part of the mass represented dry land. From the Middle Liassic transgression of sea began and sea invaded the whole Dzirula mass. Later on, in the Middle Jurassic it became an area of the intense volcanic activity and as a result a thick spilitic series was formed [Dzotsenidze *et al.*, 1953]. Following uplift of the mass turned it to land, where crust of weathering developed [Dzotsenidze, 1963]. Invasion of the Cretaceous sea resulted in the Cretaceous sedimentary cover of the mass, represented by a horizontal sequence of limestones. A new uplift freed the Dzirula mass of sea and it remained land up to the end of the Upper Eocene. Beginning of an intense folding and uplift in the Adjaro-Thrialethian geosyncline caused migration of sea from the geosyncline towards the adjoining landmasses, including the Dzirula mass. A significant part of the latter was covered by the Oligocene sea, where the Chiatura manganese deposit was formed.

Due to the rigid substratum and horizontal Cretaceous strata the Chiatura basin of the Oligocene sea represented a depression with nearly flat bottom, favourable for deposition of the continuous layers of manganese-ores and their host rocks.

As it can be seen, the Dzirula mass experienced epeirogenetic movements. Uplift, initiated in post-Oligocene time caused an extensive erosion of the Oligocene and older rocks, including the Paleozoic basement. Erosion of Oligocene strata destroyed a significant part of the Chiatura manganese deposit.

West and East of the Dzirula mass subsidence zones occur. The Kvirila depression deposit is located within the western zone of subsidence. In difference from the Chiatura deposit, the Oligocene sediments of the latter rest upon the Upper Eocene marls. The Kvirila depression directly adjoins the northern border of the Adjaro-Thrialethian geosynclinal zone, composed mainly of the Cretaceous and Paleogene volcanic formations [DZOTSENIDZE, 1964]. Evidently, concurrently to the intense volcanism and formation of volcanic sequences in the Adjaro-Thrialethian geosyncline, marls deposited in the adjoining Kvirila basin. Pre-Oligocene folding stage that uplifted the Adjaro-Thrialethian range was reflected in the Upper Eocene sediments of the adjacent basin by formation of latitudinaly trending folds with axes parallel to the Adjaro-Thrialethian range. As a result, the Oligocene basin of the Kvirila depression was characterized by an uneven bottom with alternating synclinal troughs and anticlinal rises. In the synclines a comparatively undisturbed accumulation of manganese took place, whereas the anticlinal rises are nearly devoid of manganese layers or comprise only small ore-bodies. This accounts for highly variable thickness, rapid tapering out and nearly lenticular character of the ore-bearing horizon in the Kvirila depression. It is to be noted, that folding proceeded during the Oligocene as well and hence, the Oligocene sediments are synorogenic.

The Upper Eocene marls of the Kvirila depression contain some opal and are correctly referred to as opoka marls [A. MAKHARADZE, D. CHELIDZE]. Even single sponge spicules are present, intensely replaced by calcite. In the WSW part of the Kvirila depression the Upper Eocene marls grade laterally into sandy-argillaceous opokas, that are tuffitic in appearence because of a significant content of the fresh andesine grains.

As to the silicites represented by opokas and spongiolites, they are abundant in both the Chiatura and Kvirila depression deposits. It is very indicative that silicites are absent from the eastern part of either deposits, their thickness gradually increasing towards the West. For example, in the western margin of the Kvirila depression their thickness attains 150 m but here they grade laterally into the Upper Eocene marls. Usually spongiolites form large lenses in opokas. In both Chiatura and the Kvirila depression silicites are laterally substituted eastward by clays of so called Maikopian type, containing montmorillonite as the principal clay component.

The above data show that in certain regions silica deposition begins in the Upper Eocene and increases in the Oligocene. Thus the postvolcanic hydrothermal activity supplying silica and later on also manganese, began in the Upper Eocene and not in the Oligocene.

The single sponge spicules in the Eocene marls suggest a meagre silica supply. With increase of the silica supply an extensive accumulation of opokas begins and in some favourable areas sponges flourish and spongiolites are formed.

As it is well known, land-derived silica is appreciable in sediments, only if the latter are formed in environments of slow supply of the terrigenous detritus. Consequently, the time of the Upper-Eocene marl deposition should be most favourable for silica accumulation. But just the opposite is observed. The Upper Eocene marls contain an insignificant amount of silica. On the contrary, accumulations of the Oligocene sandy-argillaceous sediments is accompanied by an extensive deposition of opokas, spongiolites, glauconite, montmorillonite and manganese over large areas of the basin.

This fact can be explained only by intensification of volcanic hydrothermal-activity in the late Upper Eocene and Oligocene, related to termination of the intense Eocene volcanism in the adjacent Adjaro-Thrialethian geosyncline.

Comparison of the above facts draws to the conclusion that manganese deposits of Chiatura and the Kvirila depression were formed at the bottom of the Oligocene sea, within two distinct depressions, separated by a threshold of the Cretaceous limestones. *(Fig. 2)*. Besides, the Chiatura depression was from the beginning

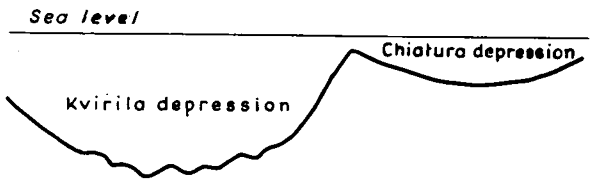

Fig. 2

situated at a higher level, as indicated by the quartzose sands and sandstones that underlay the ores. These sandstones are thickening eastward up to 25—30 m and gradually taper out towards the West. In the Kvirila depression these ore-subjacent terrigenous strata are completely absent. The Kvirila depression was gradually subsiding: this processus persisted also in the Quaternary, as it is evidenced by a thick (20 m) alluvium and puissant terraces, elevated at 80—100 m above the valley-level. In distinction from the Kvirila depression, the Chiatura depression was affected by small-scale eustatic movements, but in the Lower Oligocene, here too, subsidence prevailed, that was changed later by an intense uplift. This accounts for the fact, that the Chiatura plateau is situated presently at 500 m above the Kvirila depression *(Fig. 3)*.

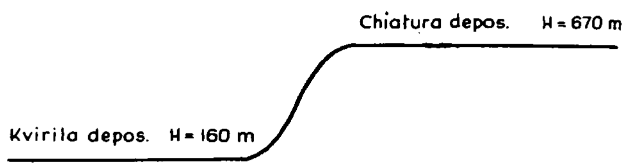

Fig. 3

An analogy with the Red Sea depressions is apparent, where hot brines deposit Cu, Zn, Pb sulfides, irone oxides, manganese, montmorillonite [DEGENS, E. and D. ROSS, 1969].

In the Red Sea depressions hydrothermal solutions rise from the depth and as we suggested [DZOTSENIDZE, 1972], they are of volcanic origin. The fact that bottom hydrothermal of the depression Atlantis-II are manifested locally and do not result from the deep migration of sea-water from the Gulf of Aden is confirmed by the new studies of the water and temperature regime in this depression [ROSS, 1972].

Presence of the silica sponges indicates that no brines existed in the depressions of the Oligocene sea. But the same fact suggests that water in these depressions was warmer than elsewhere in the Oligocene sea, as far as no sponges are found beyond their limits.

Let us consider the last and most important question of the genesis of the Oligocene manganese deposits of Georgia. What is the explanation for a strong manganese enrichment of the hydrotherms emitted at the bottom of the above depressions? Geosynclinal volcanism was active during the Jurassic and Cretaceous, but no manganese deposits are related to their postvolcanic activity.

Our approach to the problem is based on the widely known concept by V. M. GOLDSCHMIDT [1938] that many trace elements present in magma do not form their own minerals but are trapped in the crystalline lattice of the rock-forming minerals. The latter can accept in their lattice only trace elements with ionic radii compatible to those of the principal elements of the mineral.

This approach allowed the author to explain a nearly exclusive connection of the Georgian barite deposits with the Middle Jurassic volcanic series [DZOTSENIDZE, 1948, 1965]. As it is known, barium and potassium have closely compatible ionic radii and barium is isomorphous in the lattice of potassium feldspars. But as far as the Middle Jurassic volcanic rocks are nearly devoid of potassium feldspar, barium present in the melt was unable to enter rockforming minerals during crystallization, was removed by postvolcanic solutions and later formed numerous hydrothermal veins, that are widespread in the Middle Jurassic volcanic series of Transcaucasia [DZOTSENIDZE, 1945, 1948, 1960].

From the above considerations follows that manganese enrichment of the Oligocene hydrothermal solutions can be explained by the character of the Paleogene volcanic activity of the Adjaro-Thrialethian geosynclinal zone and by manganese behaviour in the magmatic melt.

The Paleogene effusive rocks of the Adjaro-Thrialethian range are represented mainly by augite porphyrites [DZOTSENIDZE, 1948], where manganese is present predominantly in the augite. The manganese content of these rocks approaches the clark value (0,1—0,15% MnO). But in the northern border of the geosyncline that is directly to the Kvirila depression and Dzirula mass, the Middle and Upper Eocene series attaining 1500—2000 m in thickness consists of potassic basalts, trachytes, trachyandesites, trachytic rocks being dominant and forming 2/3 of the whole sequence [DZOTSENIDZE, 1948, 1966; LORDKIPANIDZE, NADAREISHVILI, 1964]. Trachytes contain but minor augite and, as a result, their manganese content is 0,03—0,06%, that corresponds 1/2—1/3 part of manganese, present in the parental magmatic melt (0,1—0,15%).

Consequently, during formation of these volcanic rocks considerable amount of manganese remained in the residuum and later enriched in the postvolcanic hydrothermal solutions. It can be calculated that the quantity of manganese received by the hydrothermal solutions in this way, is to originate several deposits of Chiatura scale.

The fact, that residual manganese was removed by hydrothermal solutions is suggested by the manganese veins reported from the Middle und Upper Eocene rocks in several localities of the Adjaro-Thrialethian range.

The polarity in manganese content of effusive rocks and postvolcanic hydrothermal solutions is confirmed by some other Georgian examples: *1)* The Cretaceous dacites and albitophyres contain traces up to 0,05% of manganese.Numerous, quite intense hydrothermal manganese manifestations and deposits are related to these rocks; *2)* the Paleocene dacites of some regions with the similarly low manganese content (up to 0,05%) also comprise manganese veins and layers; 3) a reverse example is provided by the rocks of the Middle Jurassic volcanic series. They are characterized by an elevated manganese content (from 0,12 up to 0,52%) but even minor hydrothermal manifestations of manganese are absent from the series, that is widespread over the whole Transcaucasia [Dzotsenidze, 1969].

We suggest that the polarity-rule of trace element contents in magmatic rocks and related hyrothermal solutions is true not solely for barium and manganese but is applicable to other trace elements. For example, Beus [1959] demonstrated that beryllium-bearing pegmatites are related to granites characterized by a low beryllium content. The same is true for tin. Hydrothermal tin deposits appear to be connected with granites with tin content below clark.

Further investigation in this line would be of doubtless interest.

Along with manganese hydrothermal solutions supplied iron, that formed thin intercalations of iron oxides within the ore-bearing sequence, predominantly in its lower part. But the major part of iron entered glauconite, also, very abundant in the ore-bearing sequence. In certain cases glauconite forms up to 50% of the whole rock. A part of iron entered iron rich montmorillonite.

Thus, the Chiatura and Kvirila depression manganese deposits are sedimentary by origin, but their manganese and silica was supplied to the sedimentation basin by hydrothermal solutions and deposited according to the laws of chemogenous sedimentation. Consequently, the deposits should be considered as hydrothermal-sedimentary (volcanic-sedimentary) as far as principal ore-forming component is not land-derived, but is supplied by volcanic hydrothermal solutions.

It is to be pointed out that numerous examples of present-day manganese accumulation related to volcanic activities are known. Several of these examples have been described by the present author [Dzotsenidze, 1969].

REFERENCES

Betekhtin, A. G. [1946]: Economic manganese ores of the USSR. USSR Ac. Sci. Press.

Beus, A. A. [1959]: Distribution of beryllium in igneous rocks. In ,,Geochemistry of trace elements related to problems of petrogenesis", USSR Ac. Sci. Press.

Dzotsenidze, G. S. [1948]: Pre-Miocene effusive volcanism of Georgia. Georgian SSR Ac. Sci. Press.

Dzotsenidze, G. S., Skhirtladze, N. I., Chechelashvili, I. D. [1956]: Lithology of the Bathonian sediments of Okriba. Ac. Sci. of the Georgian SSR, Geological Institut Press.

Dzotsenidze, G. S. [1963]: Ancient crusts of weathering in Georgia. In "Crust of weathering", vol. 5, USSR Ac. Sci. Press.

Dzotsenidze, G. S. [1964]: Problem of relationship between volcanism and tectonics on the example of the Caucasus. Proc. of 22th IGC.

Dzotsenidze, G. S. [1965*a*]: On the role of isomorphous trapping of barium and manganese for the postmagmatic product enrichment in these elements. In "Problems of Geochemistry", Edit. "Nauka".

Dzotsenidze, G. S. [1965*b*]: On the genesis of the Chiatura manganese deposit. "Litologia i poleznie iskopaemie", No I.

Dzotsenidze, G. S. [1966]: Tectonic position of the alkaline rocks of the Caucasus. In "Genesis of alkaline rocks", Edit. "Nauka".

Dzotsenidze, G. S. [1969]: Role of volcanism for the genesis of sedimentary rocks and ores. Edit. "Nauka".

Dzotsenidze, G. S. [1972]: Red Sea hot brines and problems of the volcanic-sedimentary lithogenesis. "Geologia rudnikh mestorozhdenii', t. XIV, No. 5.

Goldschmidt, V. M. [1938]: Principles of distribution of chemical elements in minerals and rocks. In "Papers on the trace element geochemistry". Edit. GONTI.

Hot brines and recent heavy metal deposits in the Red Sea. Edited by E. DEGENS and D. ROSS. Springer Verlag, New York, 1969.
LORDKIPANIDZE, M. B., NADAREISHVILI, G. SH. [1965]: Paleogene volcanism of Northern Guria and Imeretia. In "Problems of the Geology of Georgia" for the XXII IGC Session. Edit. "Metsniereba".
ROSS, D. A. [1972]: Red Sea hot brine area. Science, v. **175**, No. 4029.
STRAKHOV, N. M., STERENBERG, L. E. [1965]: On the problems of genetic type of the Chiatura dedeposit. "Litologia i poleznie iskopaemie". Edit. "Nauka".

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