Acta Mineralogica-Petrographica, Szeged, XX/2, 313—323, 1972.

GENETIC TYPES OF SEDIMENTARY MANGANESE FORMATIONS

V. P. RAKHMANOV and V. K. TCHAIKOVSKY

ABSTRACT

Sedimentary and volcanogenic-sedimentary manganese ore formation for the determination of main manganese formations characterized by specific features (lithologic, volcanogenic, facies, tectonic) is discussed. Manganese formations are divided into three main types: platform, transitional (subplatform and subgeosynclinal) and geosynclinal corresponding to large tectonic elements of the earth crust. According to lithologic features every type is subdivided into subgroups of manganese formations — terrigenous, carbonate and volcanogenic the quantitative correlation of which is different.

Taking into consideration difficulties of ascertainment of the true nature of manganiferous solutions main attention was paid to paragenetic connections and rock assemblages accompanying manganese ore-formation during the study of sedimentary manganese ores and metallogeny in different tectonic parts of the earth crust. A genetic classification of sedimentary manganese formations is suggested. Its scheme is: types of manganese formations—subgroups — manganese formations — deposits.

At present there are many works dealing with the geochemistry of manganese, regularities of manganese deposit distribution and conditions of their formation in different details and from various positions. In this regard VERNADSKIY's [1934], FERSMAN's [1939] and BETEKHTIN's [1946] works are generally known.

Much less work is related to the study of sedimentary and volcanogenic-sedimentary manganese ore formation for clearing up chief manganese formations characterized by specific features (lithological, volcanogenic, facies, structural-tectonic). Works by SHATSKIY [1954], STRAKHOV [1960, 1968], RUKHIN [1953], VARENTSOV [1961] have made a valuable contribution to clearing up the nature of latter.

This problem is also considered in the works of ZAKHAROV [1958], DZOTSENIDZE [1965], SAPOZHNIKOV [1967, 1970], SUSLOV [1966], SOKOLOVA [1968], ROY [1966, 1969] and others. Nevertheless there is no general point of view on particular parts of this problem. Therefore in this article we shall endeavour to be guided by more widespread ideas.

As it is known, the majority of the world manganese ore resources, in particular in the USSR, belongs to sedimentary-marine deposits subdivided into true sedimentary and volcanogenic-sedimentary according to the source of ore-bearing solutions [RAKHMANOV, 1970]. When choosing the main types of sedimentary manganese ore formations it is necessary to take into account that in some cases factors of exogenetic metallogeny and exogenetic rock and ore formation are considered while in others — hypogene, in particular volcanogenic factors.

Methods which we should use during a study of deposits and drawing up prognostic metallogenic maps for manganese ores are defined by the fact that economic manganese deposits belong to sedimentary or sedimentary-volcanogenic formations. In the first place such methods are lithological-facies and formational. At the conferences in LOPI (Laboratory of Sedimentary Mineral Deposits, USSR) in 1968-1969 concerning drawing up prognostic and prognostic-metallogenic maps for manganese ores in perspective regions of Ural, Kazakhstan, Siberia and the Far East the necessity of using these methods for prognosis of manganese deposits was widely discussed. A recently published work by TCHAIKOVSKY, RAKHMANOV and KHODAK [1972] on basic principles of drawing up prognostic and prognostic-metallogenic maps for manganese ores is mainly devoted to a methodical problem.

The correlation of different genetic types is shown in the suggested classification *(Table 1)*. As stated above manganese deposits of the sedimentary type are the main commercial and the most widespread.

The task of this work is to carry out the analysis of true sedimentary and volcanogenic-sedimentary types of deposits on the basis of the formational method.

We do not deal with manganese deposits of the magmatogenic type as they are not connected with certain formations and are of no practical interest to the USSR and other countries.

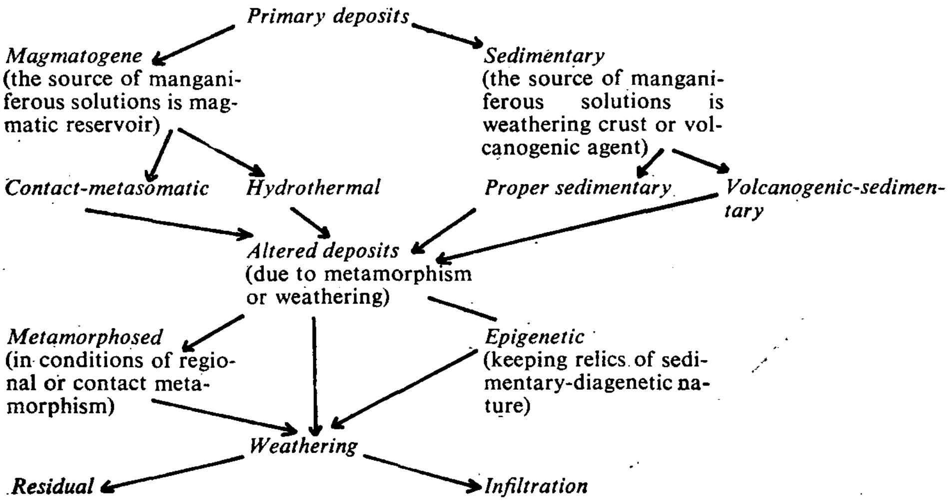
It should be noted that volcanogenic-sedimentary ore deposits are sometimes associated with small manganese-bearing veins, derivates of hydrothermal or metamorphic solutions.

Now we shall review some classificational schemes of manganese formations and also choose names for sedimentary complexes with manganese ores.

According to SHATSKIY's well known determination, the formation is a natural complex of rocks in which separate parts, i.e. beds, layers are paragenetically associated with each other both in age and spatial respect. In accordance with this determination the manganese formation is considered to be a paragenetic association of rocks in which beds (bodies) of manganese ore or similar accumulations are a constant unit of the section. The origin of manganese formations in time and space

TABLE 1

Genetic classification of manganese deposits



nearly corresponds to that of tectonic set up because they (i.e. formations) are usually separated by more or less large interruptions indicating tectonic reconstruction. Formations and tectonic set up are complete products with definite stages of the beginning and the end of a cycle.

Namely the study of paragenetic associations or formational analysis of rocks formed at different times, in any tectonic and paleogeographical environments and containing manganese ores and manganese-bearing rocks in any part of beds and layers is considered to be the basis of classificational prognostic-metallogenic schemes.

Classifying the main units-formations or subdividing every of them into smaller units one can build up one or another classificational scheme which can be used for revealing and analyzing the relationship between certain types of sedimentary rocks and associated sedimentary and volcanogenic-sedimentary manganese deposits and tectonic set up.

The most useful classification is a scheme where manganese formations are divided into three broad types: platform, transitional (subplatform and subgeo-synclinal) and geosynclinal corresponding to larger tectonic elements of the earth crust. According to lithological features every type is divided into subgroups of manganese formations — terrigenous, carbonate and volcanogenic quantitative relations in which are given in the genetic classification of sedimentary manganese formations *(Table 2)*.

As seen in the table distribution of different subgroups of manganese formations in every given tectonic type is nonequivalent. From platforms to transitional and further geosynclinal regions there are appreciable decrease of terrigenous and sharp increase of volcanogenic and partially carbonate constituents in the subgroups of formations.

The majority of world resources of manganese ores (more than 60 %) is concentrated in deposits of terrigenous formation subgroups, especially in the quartz-sand-clay formation of platform and transitional types. Unique deposits of this subdivision have been reported from USSR — Nikopol, Bol'she-Tokmaksk and Chiatura, related to deposits of Nikopol or orthoquartzite-glauconite-clay manganese formation by Varentsov [1962]. These deposits have been related to the glauconite formation by Shatskiy [1954].

We are not sure whether glauconite is a constant member of this formation and therefore we should prefer to name it a quartz-sand and clay formation, as it was adopted by the Atlas of lithologic-paleogeograpical maps of the Russian platform and its geosynclinal framing [1961].

In geological respect deposits related to the quartz-sand-clay manganese platform formation have much in common: the relation of ore concentrations to terrigenous sand-aleurite-clay, often siliceous chemogenous sediments, slope bed of manganese ore layers, their identical facies profiles. The profile changes uniformly from the shore line to the depth of the basin and is characterized by gradual change of oxide ores by carbonate ores through the intermediate zone in which mixed oxide-carbonate varieties are developed.

Common characteristics of the present formation deposits are also acknowledged by similar textular-structural ore appearance. As a rule, they were mainly formed in humid condition (Nikopol, Bol'she-Tokmaksk deposits). However, there are more or less considerable deviations connected with the fact that humid condition is changing into arid during the formation of manganese ores. For example

TABLE 2

Genetic classification of sedimentary manganese formations

Types of manganese formations	Subgroups of manganese formations and their quantitative relations (%)	Manganese formations	Deposits
Platform	Terrigenous — 75	Quartz-sand-clay	Nikopol. Bol'she-Tokmaksk — Pg_3 (Ukraina) Timna — S (Israil)
	Carbonate — 15	Dolotmite-terrigenous Limestone-dolomite	Nargeshum — P-T (Morocco) Imini-Tazdrem — Cr_2 (Morocco)
	Volcanogenic — 10	Volcanic-terrigenous Volcanic-carbonate Siliceous-iron	Pick Artillery, Lake Mid — N_2 (USA) Golconda — Q (USA) Urukum — S (?) (Mato Grosso, Brazil)
Transitional regions (subplatform and subgeosynclinal)	Terrigenous — 50	Quartz-sand-clay	Chiatura — Pg_3 (Georgia); Nizhneudinsk group — Pt_3 (Prisayanje)
	Carbonate — 20	Quartz-sand-clay „Gondite"	Madhya Pradesh — A (India) Nsuta — Pt_1 (Ghana)
	Volcanogenic — 30	Siliceous-limestone Limestone-dolomite Volcanic-terrigenous	Karadzhal — D_3 (Central Kazakhstan) Ulu-Telayk — P P_1 (West Ural) Tetritskaroik group — Pg_1 (Georgia)
Geosynclinal (eugeosynclinal and miogeosynclinal)	Terrigenous — 10	Quartz-sand-clay	Iliktinsk — Pt_3 (Pribaikalie)
	Carbonate — 30	Limestone Dolomite-limestone Siliceous-limestone	Sagan-Zaba — A (Pribaikalia) Usinsk — Cm_1 (West Siberia) Takhta—Karacha — S (Middle Asia)
	Volcanogenic — 60	Spilite-keratophyre-siliceous Porphyre-siliceous Siliceous-iron	Primagnitogorsk group — D_{1-3} (South Ural); ores of the Dharwar system — A (st. Mysore, India) Durnovsk — Cm_2 (Salair) Minas Gerais — Pt_2 (Brazil) Postmasburg— Pt_1 (RSA)

at Timna (Israel) manganese deposit copper concentrations are known to have been formed synchronously with manganese deposition [BENTOR, 1956].

Taking into account tectonic pecularities of the quartz-sand-clay manganese formation of the Chiatura deposit in the Georgian block — a hard mid massive in a geosynclinal zone, we relate it to the manganese transitional formation type although according to lithological facies, ore-mineralogical and geochemical characteristics, it is similar to that of the Nikopol deposit.

Quartz-sand-clay manganese formations of the transitional type are also typical of earlier epochs of manganese ore accumulation. So the quartz-sand-clay manganese formation is clearly distinguished among Upper Proterozoic (Riphean cycle) rock complex in Prisajnie connected with depositions of Karagass and Oselochnaya groups (the Nizhneudinsk group of manganese deposits). There is an opinion that it has been formed in subplatform conditions after the completion of Sayan tectogenesis [DYBROV, 1964]. Rocks of Karagass and Oselochnaya groups are subdivided into some series. Usually manganese mineralization is related to series in the base of which horizons of clastic and detrital depositions are developed (conglomerates, gravelites, sandstones, aleurites).

At the Iliktinsk deposit in Pribaikalia manganese ore concentrations are also related to the quartz-sand-clay manganese formation of the Goloustinsk series of Upper Proterozoic Baikal complex which had been formed in the marginal zone of the geosynclinal basin (miogeosyncline).

We suggest the gondite formation to belong to the quartz-sand-clay manganese formation.

It contains all characteristic rocks of the quartz-sand-clay formation in which gondite appearance is due to metamorphism. Primary composition of gondites was likely psammitic-pelitic with interlayers of manganese hydroxides. The present gondite formation of Central India contains rock layers composed mainly of quartz, spessartite and interbedded layers and interlayers of braunite ores, quartzites, schists. In addition to the above gondites contain hausmannite, rhodonite, manganese amphiboles, rhodochrosite.

The absence of volcanogenic products in these rocks suggests the origin of gondite manganese formation to have taken place in the outer tectonic zone of the geosynclinal region or in marginal relatively mobile belts of the platform.

Thus the name "gondite formation" in accordance with our understanding of this term can be adopted as "manganese metamorphic" in addition to "quartz-sand-clay formation".

The word "gondite" does not define the nature of the formation in its general use but only indicates a specific feature of the formation. The manganese quartz-sand-clay gondite formation is also characterized by discordant ore bedding on the base, composed mainly of gneisses, metamorphic schists [STRACZEK, SUBRAMANYAM *et al.*, 1956].

Further a part of ore beds related by VARENTSOV and others to the gondite formation with widespread volcanites which are typical of the Dharwar system (Mysore) is included into the subgroup of the volcanogenic formation. Therefore they are given the name "spilite — keratophyre — siliceous" *(Table 2)*.

Manganese content of the rocks of the manganese carbonate formation subgroup has economic significance. The following manganese formations are distinguished in this subgroup according to tectonic position, structure, composition and lithological-geochemical features of host rocks: *1)* limestone-dolomite and dolomite-terrigenous of the platform basement (deposits Imini-Tazdrem — Cr_2;

Nargeshum — P—T, Morocco); *2)* siliceous-limestone and dolomite-limestone of transitional regions (Karadzhal — D_3, Kazakhstan; Ulu-Telayk — P_1, West Priuralia); *3)* limestone, dolomite-limestone, siliceous-limestone of geosynclinal zones (Sagan-Zaba — A, Pribaikalia; Usinsk — Cm_1, Kuznetsk Alatau; Takhta-Karacha — S, Zeravshan ridge). Carbonate formations were formed in different tectonic conditions as proved by their distribution in the limits of platform, transitional and geosynclinal zones with or without manifestations of volcanism. Climate conditions during the evolution of manganese carbonate formations were different.

Manganese carbonate formations are mainly represented by shallow sea terrigenous-carbonate depositions transforming from inshore shallow water to the depth into relatively thick limestone, clayey-limestone and dolomite beds with clark and superclark up to ore concentrations of manganese when siliceous and other volcanogenic sediments occur among carbonate depositions.

Platform carbonate formations of the Morocco type (the Nargeshum deposit) are characterized by noticeable content of terrigenous red beds in the floor and roof of the formation. Oxide manganese ore beds (Imni-Tazdrem deposits, Morocco) are related to beds of Upper Cretaceous dolomites with interlayers of gypsum and anhydrites.

The well-known Ulu-Telyaksk deposit of carbonate manganese ores, in the USSR situated in the joint zone of the Russian platform and the Ural geosyncline and associated with the limestone-dolomite formation of transitional regions is also characterized by wide development of anhydrite beds of this formation. At the same time limestone, limestone-dolomite and siliceous-limestone, formations of geosynclinal zones have no distinct signs of arid conditions of their origin (Sagan-Zaba, Takhta-Karacha deposits, USSR). The dolomite-limestone formation of the Usinsk type is characterized by the relation of carbonate manganese ores to black bituminous limestones, pyritiferous carbonate and siliceous shales [Rakhmanov, 1966].

Carbonate manganese formations located in platforms and transitional regions often contain layers of rich oxide ores (braunite-hausmannite, polianite, psilomelane ores and others) in which the manganese content is 40—45 % and more. Sometimes they also have higher content of barium, lead, zinc, copper [Boulandon, Jouravsky, 1952].

In geosynclinal and transitional zones carbonate manganese formations contain mainly carbonate ores (rhodochrosite, manganocalcite, rhodochrosite-manganocalcite ores and others) with the tendency to superclark accumulation of iron, nickel, cobalt and other siderophile elements in certain facial conditions [Pushkina, 1960; Varentsov, 1962*b*; Khodak, Rakhmanov, 1966].

The content of base metals, the association with red beds and other signs confirm accumulation of carbonate manganese formations to have taken place in arid conditions; their characteristic features naturally become weak with transition from inshore-sea to deep-sea environment.

Volcanogenic manganese formations are more widely distributed in geosynclinal regions, they are less found in transitional-subplatform zones and as a rule, they seldom occur in platforms.

Recently a number of workers [Kheraskov, 1951; Shatskiy, 1954; Varentsov, 1962*a et al.*] have distinguished manganese volcanogenic-sedimentary formations subdivided due to their composition into the greenstone formation group associated with spilite-keratophyre effusive activity and the porphyry formation group with predominant development of granite-rhyolite volcanism.

The former are rather related to primary, the latter — to final phases of development of geosynclinal folded regions.

According to SHATSKIY, manganese ores of the given type are located within the formation and are not connected with interruption.

In spilite-keratophyre siliceous manganese formations poor silicate and sometimes carbonate manganese ores with small content of relatively rich oxide ores are more distributed; the oxide ores are considerably developed in the porphyry manganese formation.

Spilite-keratophyre-siliceous manganese formations are chiefly placed in eugeosyncline zones, and porphyiy formations — in miogeosynclinal zones. Greenstone formations are characterized by higher content of silica; Cu, Ni, Co, V, Cr are present in superclark concentration; Pb, Ag, Au, As are rare.

A large group of the South Ural deposits and ore manifestations is connected with spilite-keratophyre volcanism. They are situated in Devonian jasper-siliceous rocks of the Magnitogorsk synclinore in the east slope of South Ural.

Porphyry-siliceous formations are characterized by wide distribution of manganese oxide Ores — pyrolusite or braunite-hausmannite, at times associated with iron ores. They have often rather high concentrations of barium, lead, zinc and other elements. The Durnovsk deposit situated in Salair may be an example of volcanogenic-sedimentary manganese deposits of the porphyry type.

Ore enclosing rocks in the Durnovsk deposit are represented by Lower and Middle Cambrian quartz porphyry, quartzite, tuff and tuffite.

Ore bodies interbedded with quartz porphyry, tuff, quartz-sericitic schist and quartzite form a manganese ore bed of 45—60 m thickness [SUSLOV, 1967].

The siliceous-iron formation is included into the group of volcanogenic manganese formations. Manganese is known to be widely distributed as associated element in jaspilite formations which are the largest Precambrian iron beds in the world (Minas Gerais — Pt_2, Brazil; Postmasburg — P_1, RSA). Manganese ore beds are mainly typical of marginal parts of proper siliceous-iron (jaspilite) formations where iron beds with manganese clark content are transformed into limestone-dolomite rocks with higher concentrations of this element. According to tectonic conditions of formation and specific features of ore mineralization manganese siliceous-iron formations are subdivided into eugeosynclinal, miosynclinal and platform types [VARENTSOV, 1962*b*].

It should be noted that important Precambrian manganese siliceous-iron formations practically are unknown in the USSR. However, some manganese ore manifestations are genetically connected with Precambrian siliceous-iron formations (Proterozoic manganese-iron quartzites of Sosnowy Baitz series and Andotsk series in Prisaynia, manganese ore concentrations in siliceous-iron bed of Malyi Khingan).

Probably in Brazil the iron-manganese Urukum deposit (S?) is related to the siliceous-iron formation of the platform type (State Mato Grosso). Here gentle bedding of ore enclosing rocks, absence of volcanogenic products in the section and signs of metamorphic transformation are characteristic for the whole complex of terrigenous siliceous-iron (hematite) depositions (Jagadigo group, about 700 m thickness) including concordant beds of manganese (cryptomelane) ores and situated in raised or lowered blocks of the Precambrian granitic basement. Some authors suppose precipitation of manganese to have taken place in the form of hydroxide in these deposits [BARBOSA, 1956].

An example of manganese volcanogenic formations of the transitional region is the formation of the Artvin-Somkhitsk block in Tetritskaroisk district (Georgia, USSR). Beds of oxide manganese ores in the form of layers of small thickness occur in the transitional zone from the lower "flish" horizon to overlapped volcanogenic rocks of andesite-dacite composition. There are also ore-bearing tuff, tuff breccia, tuffaceous sandstone and fine conglomerate.

The volcanogenic formation subgroup of the platform type is represented by volcanogenic-terrigenous and volcanogenic-carbonate manganese formations. They are illustrated by Neogen manganese ore manifestations of Peak Artillery and Lake Mid regions in Colorado-Rio and a small Pleistocene manganese deposit in Golkonda, Central Nevada.

Some workers and especially Sokolova [1968] have shown that manganese ores in Peak Artillery and the Lake Mid regions are of continental volcanogenic-sedimentary origin connected with water environment. Manganese ores were associated with terrigenous rocks (from conglomerate to sandstone and clay) and also andesite-basalt and fine-grained tuff. They contain higher lead (up to 5 %) and copper (up to 0.3 %). The oxide (psilomelane) ores of the Golkonda deposit are embedded in the base of calcareous tuffs.

Their specific feature is high content of wolfram (up to 6.19 % WO_3, average 0.5 %). Manganese solutions were brought into basins at the relatively late period of volcanism. Their formation is connected with hydrothermal solutions which in Pleistocene rose from depths along faults and joints of the Mesozoic basement [Sokolova, 1968; Kerr, 1940].

Manganese formations in these subgroups can be divided in their turn according to the degree of metamorphism of host rocks into metamorphosed and slight metamorphosed — epigenetic. So there is a quartz-sand-clay formation characterized by absence of metamorphism in the group of transitional regions. The important example of this subdivision is the widely known Oligocene manganiferous bed of the Chiatura deposit with manganese oxide, oxide-carbonate and carbonate ores.

Another quartz-sand-clay manganese formation so called "gondite", is also included into this subgroup; its rocks had undergone intensive metamorphism and lost primary sedimentary-diagenetic appearance. Numerous manganese deposits relating to Archeozoic and Proterozoic metamorphosed rocks of ancient platforms (Indian, African, Brazilian, Australian platforms) belong to this formation, too. The most typical regions of the gondite formation are the Central province of India (Madhya Pradesh), West Africa (groups "Birrim" in Ghana and "Ancongo" in Mali) and others. The gondite formation is characterized by specific rocks from phyllite, quartz-sericite, biotite and muscovite schists to quartzite and feldspar-quartz gneiss in which there are concordant beds of braunite ores and gondite rocks. Gondites are represented by specific paragenetic assemblage: quartz, spessartite, rhodonite, bustamite, manganese amphiboles and pyroxenes, braunite, hausmannite, biotite, muscovite, plagioclases.

Further it is necessary to review the subdivision of manganese superimposed formations or formations of weathering crust as they are sometimes called. Indeed there are many manganese formations with different manganese content where physical and chemical alteration may result in the formation of new manganiferous concentrations in supergene and other conditions. In the supergene zone manganese ore beds can be formed simultaneously in some different adjoining formations or their subgroups (terrigenous, carbonate, volcanogenic). In some cases the endogenous factor is important for secondary enrichment of manganese ores too. Therefore the formations with such ore beds should be named as primary formations adding words "with superimposed manganese protore".

The determination of the source of manganiferous solutions is of great importance for a correct relating of sedimentary manganese formations to any type or subgroup. So in conclusion we shall concern the source of manganiferous solutions.

The review of numerous works concerning this problem shows that the opinions of authors on the source of ore solutions vary at times. Every worker tries to confirm his point of view, moreover their concepts on the source of manganiferous solutions for the same object differing.

The first example: Dzotsenidze [1965], Khamkadze [1971] and others give data for the important Chiatura manganese deposit (USSR) showing that post-volcanic hydrothermal solutions of Upper Eocene volcanism but not weathering crust of eroded land were the source of manganese in the Oligocene sea of Georgia. At the same time concepts of Betekhtin [1946], Strakhov [1964] and other geologists on the Chiatura deposit as proponents of the opinion about the source of manganese from weathering crust of the Dzirulsk granitoid massive and Bajocian porphyrite series are generally known.

The other example: Sokolova [1969], Mirtov, Tsykin *et al.* [1964] concerning the well-known Lower Cambrian Usinsk deposit of carbonate manganese ores in Kuznetsk Alatau suggest the formation of this deposit to have taken place in close connection with volcanic activity; synchronous volcanic exhalation was the source of ore solutions.

Varentsov [1962] and other authors, however, regard the Usinsk deposit to be "typical exogenous formation which was not controlled by volcanic processes ... Ore material was brought due to deep chemical alteration of land".

The problem of the manganese source is complex and debatable. Natural data and experiments suggest manganese in suspension and solution to have been lost by supergene waters from contemporary weathering crust. Some data suppose manganese to have been brought into sedimentary basins due to volcanic activity. And the longer (in the scale of geological time) manganese combinations which are in equilibrium with surrounding water environment of seas and oceans are kept in solution the more complicated is the genetic restoration of primary nature of manganese. Hence there are contradictory opinions concerning even such unique (in respect of manganese concentration) and well studied Oligocene deposits of the Black Sea basin as Nikopol, Bol'she Tokmaksk, Chiatura.

Important data are given by Skopintsev and Popova [1963] who estimated total manganese in the water of the Black Sea to be about 100 million tons. It is not exception as Sapozhnikov [1967] assumes that manganiferous ore sediments may be formed in inshore parts of the basin at favourable conditions (tectonic reconstruction causing stable rising currents etc.).

It is extremely difficult to ascertain the true nature of manganiferous solutions even by analogy with recent manganese ore formation. Taking into account the above, much attention was paid to paragenetic connections and rock assemblages accompanying manganese protore while studying sedimentary manganese ore formation and metallogeny in different tectonic parts of the earth crust. On this basis our genetic classification of sedimentary manganese ores has been built up.

Detailed geological study and ascertainment of the genesis of manganese deposits are very important as it allows to find out causes of paragenetic connections between manganese formations and inclosed deposits. On the basis of revealed regularities it is possible scientifically to set up prognosis and search for economic manganese ores. Clearing up paragenetic relations should be considered as necessary stage helping to learn their genetic connections.

REFERENCES

Atlas of lithologic-paleogeographical maps of the Russian platform and its geosynclinal framing. Moscow, Izd. AN SSSR, 1961.

BARBOSA, O.: Manganese at Urucum, state of Mato Grosso, Brasil. In: XX Congresso geologico international. Symposium del manganeso *3*, Mexico, 1956.

BENTOR, I. K.: The manganese occurrences at Timna (Southern Israel), a Lagoonal deposit. In: XX Congresso geologico international. Symposium sobre yacimientos de manganeso *4*, Asia y Oceania. Mexico, 1956.

BETEKHTIN, A. G.: Commercial manganese ores of USSR. Moscow, Izd. An SSSR, 1946.

BOULANDON, J., JOURAVSKY, G.: Manganese. Geologie des gites mineraux marocains. XIX. Congres geologique international. Monographies regionales. 3-e ser., Maroc, N 1, Rabat, 1952.

TCHAIKOVSKIY, V. K., RAKHMANOV, V. P., KHODAK, YU. A.: Principles of drawing up prognostic-metallogenic maps of manganese formations. Moscow, Izd. Nedra, 1972.

DIBROV, V. E.: Geology of central West Sayan. Moscow, Izd. Nedra, 1964.

DZOTSENIDZE, G. S.: Influence of volcanics on formation of sediments. Moscow, Izd. Nedra, 1965.

FERSMAN, A. E.: Manganese. In: "Geokhimiya", *4*, Moscow, Gosnauktekhizdat, 1939.

KERR, P. E.: Tungsten-bearing manganese deposits at Golconda, Nevada. Geol. Soc. Amer. Bull, *51*, 1940.

KHAMKHADZE, N. L.: Lithology of Oligocene manganese-bearing depositions of the north Georgian block. Tbilisi, Izd. Metsniereba, 1971.

KHERASKOV, N. P.: Geology and genesis of Eastern Bashkirian manganese deposits. In: "Voprosy litologii i stratigraphii SSSR. Pamyati akademika A. D. Arkhangel'skogo. Moscow, Izd. AN SSSR, 1951.

KHODAK, YU. A., RAKHMANOV, V. P.: Geochemistry of ore bed of the Usinsk deposit and underlying rocks. In: "Mestorozhdeniya margantsa Kuznetskogo Alatau". Moscow, Izd. Nauka, 1966.

MIRTOV, YU. V., TSYKIN, R. A., VALYUZHENICH, Z. L., ALEXANDROV, K. I.: Manganese and phosphorite Lower Cambrian and Upper Precambrian (Sinian) formations of West Siberia, Trudy *V* Vsesoyuzny litolog. Soveshchaniya. Tom. *II*, SO, AN SSSR, Novosibirsk, 1964.

PUSHKINA, Z. V.: On geochemistry of the Usinsk manganese deposit. Moscow, Dokl. AN SSSR, t. *135*, N 1, 1960.

RAKHMANOV, V. P.: Types of ores and host rocks of the Usinsk deposit. Moscow, Izd. Nauka, 1966.

RAKHMANOV, V. P.: On regularities of localization of manganese deposits and geological prognostic factors. In: "Voprosy rudnichnoy geologii. VIOGEM. Ch. 1. Belgorod, 1970.

ROY, S.: Syngenetic manganese formation of India, Jadavpur University, Calcutta, 1966.

ROY, S.: Classification of manganese deposits. Acta Mineralogica-Petrografica Szeged *19*, 67—83, 1969.

RUKHIN, L. B.: Elements of lithology. Moscow, Gostoptekhizdat, 1953.

SAPOZHNIKOV, D. G.: Some geological conditions of formation of manganese deposits. In: "Marganzevye mestorozhdeniya SSSR. Moscow, Izd. Nauka, 1967.

SAPOZHNIKOV, D. G.: Types of manganese deposits of USSR. In: "Sostoyanie i zadachi sovetskoi litologii". Moscow, Izd. Nauka, 1970.

SHATSKIY, N. S.: On manganese formations and metallogeny of manganese. Izv. AN SSSR, ser. geol., N 4, 1954.

SKOPINTSEV, B. A., POPOVA, T. P.: On manganese accumulation in waters of hydrogen sulphide-bearing bassins in the light of the Black Sea. Trudy GIN AN SSSR, vyp. 97, 1963.

SOKOLOVA, E. A.: Some regularities of localization of concentrations in manganese volcanogenetic-sedimentary formations. In: "Marganzevye mestorozhdeniya SSSR". Moscow, Izd. Nauka, 1967.

SOKOLOVA, E. A.: Regularities of formation of volcanogenic-sedimentary manganese ores. In: "Osadkoobrazovanie i poleznye iskopaemye vulkanicheskikh oblastei proshlogo", Moscow, Izd. Nauka, t. II, 1968.

STRACZEK, J., SUBRAMANYAM, M. R. *et al.*: Manganese ore deposits of Madhya Pradesh. In. XX Congreso geologico international. Symposium sobre yacimientos de manganeso *4*, Asia y Oceania. Mexico, 1956.

STRAKHOV, N. M.: Main types of litogenesis. Vol. 1—2. Moscow, Izd. AN SSSR, 1960.

STRAKHOV, N. M., SHTERENBERG, L. E.: On genetic type of the Chiatura deposit. Litol. i. polezn. iskop., N 1, 1964.

STRAKHOV, N. M., SHTERENBERG, L. E., KALINENKO, V. V., TIKHOMIROVA, E. S.: Geochemistry of sedimentary manganese process. Trudy GIN AN SSSR, vyp. 185. Moscow. Izd. Nauka, 1968.