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REPORT ON THE SYMPOSIUM ON THE GEOLOGY AND GEOCHEMISTRY OF MANGANESE AND ASSOCIATED METALS; 27TH INTERNATIONAL GEOLOGICAL CONGRESS, MOSCOW

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The Symposium S. 12. 2. 2 Geology and Geochemistry of Manganese and Associated Metals was held August 5—9, 1984, in the framework of the 27th International Geological Congress. 39 reports covering the following 3 main problems were discussed: 1. mineralogy and geochemistry of manganese—4 reports; 2. genesis of manganese deposits on the continents — 15; 3. manganese and associated metals on the floors of recent basins — 20. The problem was discussed at the joint sessions with the theme C. 06. 1. 3. entitled. "Regularities of the Origin and Distribution of Metalliferrous Sediments and Ferromanganese Nodules."

The Symposium was organized by the Commission on Manganese of the International Association on the Genesis of Ore Deposits (IAGOD) and by the Project 111. "Genesis of Manganese Ore Deposits" of the International Geological Correlation Programme.

1. On the problem of *Mineralogy and Geochemistry of Manganese* the review by R. GIOVANOLI (University of Berne, Switzerland) "Layer Structures and Tunnel Structures in Manganates" was of great scientific interest. Ternary Mn oxide phases often having a layer structure were classified as phyllomanganates. Synthetical experiments have shown that they have a relatively rigid lattice and can accomodate a considerable amount of Co and Ni ions without any alteration of the unit cell. These associations are known as asbolites. Among the 10 Å- phyllomanganates there is a group of Mn oxides the structure of which is stable only in the presence of Co, Ni, Zn, Cu or other transition metal ions which are accumulated and built into the lattice of these compunds. The dehydration products of this group of 10 Å-manganates form the group of 7 Å-phyllomanganates including two minerals — birnessite and ranciéite.

In the presence of ions the radius of which is about 1.5 Å, like K^+, NH_4^+, Ba^{2+} manganates (IV) preferably form a lattice with tunnels accomodating these ions. These tectonomanganates (IV) include such minerals as hollandite and psilomelane (lately known as romanéchite). Upon heating psilomelane transforms *via* structural intergrowth into hollandite. It's notable that tunnel manganates (IV) cannot exchange ions. Studies of monomineral samples have shown that todorokite is a mineral though its structure is still debatable.

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These are valuable data for the interpretation of Mn, Ni, Cu and other transition metals ore formation in the ocean as the highest concentrations of these metals in nodular ores are associated, as a rule, with 10 Å- manganate phases.

In the report "Mineralogy and Mineral Chemistry of Metamorphosed Manganese-Oxide Ores and Manganese Silicate-Oxide Rocks — the example from the Precambrian Sausar Group, India" by BHATTACHARYYA, P. K. DASGUPTA, S., ROY, S. (Jadavpur University, Calcutta, India), FUKUOKA, M., HIROWATARI, F. (Kyushu University, Fukuoka, Japan) it was shown that in the process of progressive metamorphism fO_2 was different in ores and enclosing pelitic rocks. The authors came to the conclusion that the composition of the fluid phase in the contrasted environment was internally buffered by the reacting minerals.

The report by CHERNYSHEV, L. V., GELETII, V. F. (Institute of Geochemistry of the Siberian Branch of the USSR Academy of Sciences, Irkutsk) "On Geochemistry of Manganese in Endogenic Processes" contains experimental data contributing to the understanding of formation processes of hydrothermal manganese ores and metal-bearing sediments. It is shown that manganese is accumulated in endogenic fluids in wide temperature ranges and remains in them (stable forms in solutions and absence of efficient precipitants) even after removal of other ore minerals from the aqueous solutions. The accumulation of manganese due to its removal from the fluid system is predominantly going on in the superficial environment while oxygen is the main precipitant of the element.

The report by KALININ, V. V. (Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry of the USSR Academy of Sciences, Moscow, USSR. "Alkaline and Alkaline-Earth Mineralization at Manganese Ore Deposits of the USSR Far East" presents the characteristics of new manganese minerals, formed when the processes associated with the Mesozoic magmatism were superimposed on the Paleozoic and, probably, originally volcanogenic sedimentary manganese ores.

2. The problem of *Genesis of Manganese Deposits on the Continents* was dealt with in the report "Genetic Aspects of Manganese Deposits Formation in the Geological History of the Earth Crust" by VARENTSOV, I. M. (Geological Institute of the USSR Academy of Sciences), RAKHMANOV, V. P., GURVICH, E. M. (Institute of Lithosphere of the USSR Academy of Sciences) and GRASSELLY, GY. (Szeged University, Hungary). The authors made an attempt to synthesize data on the evolution of the manganese ore process. The study revealed that from the Archean till the Paleozoic there was no evidence of manganese ore sedimentation in deep-water basins, the sedimentation was registered in the shallow-water environment practically in all the regions. In the Jurassic the formation of nodules and accumulation of metalliferous sediments was established in pelagic conditions (Alpine region, Timor and Roti Islands). At the Paleogene-Neogene boundary the intensive formation of ferromanganese nodules in the World Ocean took place which followed the invasion of Antarctic waters northwards.

Another interesting report on this theme was made by BEUKES, N. J. (Rand Afrikaans University, Johannesburg, South Africa) "Sedimentology of the Proterophytic Kalahari Manganese Deposit, Transvaal Supergroup, South Africa". The author presented the data on geology and conditions of formation of the gigantic hydrothermal sedimentary manganese deposit of Kalahari situated in the Hotazel formation of the Early Proterozoic Transvaal Supergroup. The estimated ore resources amount to 7500 million tons with the content of Mn 30—48% and Fe 4—15%. It is a bedded deposit, manganese ores are interbedded with iron-ore jaspilitic formations. The deposit consists of tree beds of relatively non-metamorphosed peloidal

kutnahoritic braunite lutite. According to BEUKES, N. J., the ores are of volcanogenic sedimentary origin and belong to the greenstone jasperoid association bound to manganese deposits. The ores are overlaid and interfingered by andesitic pillow lavas and hyaloclastites. Jaspilites were deposited more proximally to the volcanic source while manganolutites rather more distal. The ore-bearing sequence grades upwards into clastic deep water carbonates deposited in the front of a prograding shallow water carbonate platform.

The report by VEIMARN, A. B. (Moscow State University), BUZMAKOV, E. I., ROZHNOV, A. A. and SCHIBRIK, V. I. (the Ministry of Geology of the Kazakh SSR, USSR) "Famennian Manganese Ore Epoch in Kazakhstan" was devoted to genetically close hydrothermal sedimentary ferromanganese ore formations. However, the resources of Kazakhstan ore deposit are considerably less in comparison with Kalahari deposit, and the volcanic activity is also less manifested. The main deposits are associated with siliceous-carbonate flyshoid formation.

The report by the Australian geologists BOLTON, B. R. (La Trobe University) and FRAKES, L. A. (Monash University) "On the Origin of Manganese Giants: A Preliminary Comparative Investigation of the Chiatura (USSR) and Groote Eylandt (Australia) Deposits" and the report by the same authors together with MCHUGH, L. "The Geology and Geochemistry of Secondary Manganese Deposits on Groote Eylandt" were of considerable interest. The papers give general characteristics of the genesis of the deposits laying the emphasis on the hypergene processes in the formation of the most rich cryptomelan-pyrolusite ores of the Groote Eylandt.

VUJANOVIĆ, V. (Geological Institute, Beograd) in his report "Genetic Characteristics of Manganese Deposits in Yugoslavia" comes to the conclusion that they are mainly of moderate size, predominantly of volcanic-sedimentary origin and are situated in the "Diabase-chert formation" (from the Devonian to the Cretaceous including).

MORITANI, T. (Geological Survey of Japan) in his paper "Geology of Neogene Bedded Manganese Ore Deposits of Japan" characterized these deposits as hydrothermal sedimentary and divided them into two subtypes. Those occurring on the Japan Sea Coast show more sedimentary features, while the others occurring in the Kuroko Belt, show more influence of the hydrothermal activity.

KOSKI, R. A. and HEIN, J. R. (Geological Survey of the USA) in the report "Volcanogenic-Hydrothermal Manganese Deposits in the Western Cordillera" distinguish three groups of deposits: 1) deposits in chert-basalt and chert-graywacke sequences of the Paleozoic (Nevada) and of the Mesozoic (the Franciscan assemblage in California); 2) deposits in sequences of pelagic limestone and basalts (the Eocene of the Olympic Peninsula); 3) deposits in continental sedimentary and volcanic rocks. The first two groups are represented by numerous small deposits. The third group is represented by large Miocene and Pliocene deposits of low grade oxide manganese ores, interbedded in sandstone, conglomerate, tuff and gypsum overlying latitic andesites. The sequence was formed during incipient rifting related to the opening of the proto-Gulf of California.

A number of reports made by the Soviet geologists contained new data on manganese deposits of the USSR: GRIBOV, E. M., CHUKHNINA, L. S. (Institute of Lithosphere of the USSR Academy of Sciences) "Manganese Accumulation in the Area of the Enisei Chain of Hills"; YASHVILI, L. P. (Institute of Geological Sciences of the Academy of Sciences of the Armenian SSR) "Mineral Peculiarities of Different Genetic Types of Manganese Ores in the Armenian Republic"; DANILOV, I. S.

(Dnepropetrovsk State University) "Some Aspects of Genesis of Nikopol Manganese Ores"; MACHABELI (Caucasian Institute of Mineral Resources) "Genetic Model of Manganese Ore Formation in the Oligocene Deposits in the Caucasus"; LIPAEVA, A. V., PAVLOV, D. I. (Institute of Ore Deposits Geology, Petrography, Mineralogy and Geochemistry of the USSR Academy of Sciences) "Iron, Manganese and Metals Closely Linked with Them Occurring in the Paleochannel ways of Discharged Subterranean Waters in the Northern Near-Aral Sea Area".

The reports delivered by MACHAMER, J. F. (US Steel Corporation, USA) "Classification of Manganese Deposits. The Point of View of a Field Geologist" and by MSTISLAVSKIY, M. M. (Ministry of Geology of the USSR) "The Mechanism of Manganese Deposits Formation on the Continents" presented the analysis of data on a great number of deposits in the World.

3. The most informative reports on the problem of *Manganese and Associated Metals on the Floors of Recent Basins* contained data on formation conditions, on the regularities of distribution and on evaluation of Co-rich ferromanganese crusts on the Ocean floor: HALBACH, P. and PUTEANUS, D. (Institute für Mineralogie und Mineralische Rohstoffe, Technische Universität, Clausthal, FRG) "Cobalt-Rich Ferromanganese Crusts from Central Pacific Seamount Regions — Composition and Formation"; HEIN, J. R. (USA) "Cobalt-Rich Ferromanganese Crusts from the Central Pacific"; MANHEIM, F. T. and LANE, K. M. (US Geological Survey) "A World Wide Data Base for Ferromanganese Crusts in the Oceans". These crusts are considered as potential ores due to a high cobalt content (up to 2%). According to the data of the expedition convened on the MRV "Sonne" (FRG) in 1981, which were lately confirmed by the study of the US Geological Survey, the Mid-Pacific Seamounts region is the most promising for the industrial development. In the region of the Mid-Pacific Mountains of the Line Islands the crust thickness riches 2 cm containing 1—2% Co at the depth of 2500 m. At present the US Geological Survey carries out a wide programme of studies of these Co-rich ores a computer data base is set up, oceanographic and geochemical surveys using the most advanced technology are planned. It is emphasized that the oxidizing diagenesis plays a certain role in the development of the nodules in the abyssal regions, the bottom waters reflecting geochemical processes in the ocean is the source responsible for the formation of crusts and nodules on the seamounts.

The paper by MORITANI, T., USUI, A., NAKAO, S. and NOKARA, M. (Geological Survey of Japan) "Manganese Nodule Deposits in the Northern Central Pacific Basin" presents the results of a five year programme. There are detailed data on the distribution of different morphologic types of nodules reflecting the source of ore components supply. *a)* Interstitial waters as the metal source for the nodules of rough surface, characterized by 10 Å manganate and high grade of Mn, Ni, Cu; *b)* bottom waters were the metal source for the nodules with a smooth surface, characterized by δ-MnO_2, rich in Fe, Co. The emphasis is laid on the correlation between types of nodules and geological setting, water currents and peculiarities of sedimentation.

The report by SKORNYAKOVA, N. S., BATURIN, G. N. and MURDMAA, I. O. (Shirshov Institute of Oceanology of the USSR Academy of Sciences) "Ferromanganese Nodules of Subequatorial Ooze of Radiolarian Belt of the Pacific Ocean" is devoted to the variations in mineral and chemical composition of nodules occurring in the zone of high biological productivity related to the latitudinal zonation. It is shown that the highest Ni, Cu, Mn concentrations occur in the nodules on the both sides from the equator along the periphery of the biologically productive zones. Three

types of nodules are distinguished: sedimentary (hydrogenic), sedimentary-diagenetic and diagenetic.

SHNJUKOV, E. F. and ORLOVSKY, G. N. (Institute of Geological Sciences of the Academy of Sciences of the Ukranian SSR, USSR) in their report "Iron-Manganese Nodules of Northern and Equatorial Part of Indian Ocean" show wide distribution of multilayered bodies of nodules, underlying the role of endogenic processes as a source of ore-bearing components.

As a rule, the reports on this theme contain a lot of factual data usually presented in the graphic form. Most reports are detailed regional studies: HAYNES, B. W, LAW, S. L. and BARRON, D. C. (Bureau of Mines, Avondale, Maryland, USA) "The Mineralogy and Geochemistry of Pacific Manganese Nodules"; APLIN, A., CRONAN, D. S. (Imperial College, London, UK) "Ferromanganese in the Western Central Pacific"; PLÜGER, W. L., KUNZENDORF, H. and FRIEDRICH, G. (Technical University, Aachen, FRG) "Rare Earth Elements in Manganese Nodules from the South West Pacific Basin"; BOLTON, B. R., BURNS, R. B. and FRAKES, L. A. (Australia) "On the Geochemistry and Origin of Polymetallic Crusts from the d'Encastieaux Zone, South-West Pacific Ocean"; PIPER, D. Z., SWINT, T. P. (US Geological Survey) "Distribution of Ferromanganese Nodules in the Pacific Ocean"; BAZILEVSKAYA, E. S. (Commission on the Problems of the World Ocean of the USSR Academy of Sciences) "About the Mechanism of Manganese Nodules Formation"; EMELYANOV, E. M. (Shirshov Institute of Oceanology of the USSR Academy of Sciences, Atlantic Department, Kaliningrad, USSR) "Geochemistry of Manganese and Iron in the Atlantic Ocean Basin"; MAKEDONOV, A. V., GOLOVIENOK, O. M. and KRIVULINA, Y. A. (All-Union Geological Research Institute, USSR) "Classification of Recent Manganese Nodules"; WAKEFIELD, S. J. (University of Swansey, UK) "Deep Sea Metalliferrous Deposits: How Significant Are They?"; GRAM-OSIPOV, L. M., BYCHCOV, A. S., VOLCOVA, V. S., TISHENKO, P. YA. and CHICHKIN, R. V. (Pacific Oceanological Institute of the Far East Scientific Centre of the USSR Ac. of Sci., Vladivostok, USSR) "Physical and Chemical Problems of Formation of Ferromanganese Nodules". The report "World Distribution of Metal-Rich Subsea Manganese Nodules: a Summary" by MCKELVEY, V. E., WRIGHT, N. A. and BOWEN, R. W. (US Geological Survey) was of considerable interest. General characteristics of distribution of ferromanganese nodules in the World Ocean were inferred on the basis of computer processing of geochemical data.

The following reports were devoted to the study of fossil nodules: MINDSZENTY, A., GALÁCZ, A., DODONY, I. (Eötvös L. Univ., Budapest, Hungary), CRONAN, D. S. (UK) "Paleoenvironmental Significance of Ferromanganese Oxide Concretions from the Hungarian Jurassic", VARNAVAS, S. (Univ. of Patras, Greece) "Comparative Study of Fossil Manganese Nodules from Two Areas in Greece".

The theses of almost all the above mentioned reports were published by the "Science" Publishing House.

The sessions of the Symposium were held at M. V. Lomonosov Moscow State University. The participants visited the exhibition "Manganese Ores of the USSR and Other Countries" which was specially organized for the 27th International Geological Congress, at the Museum of the Earth Science of Moscow State University, We should mention the report made by SOREM, R. K. on the establishment of the Museum of manganese ores at Pullman University (Washington, USA). The author urged the participants of the Symposium to contribute to the museum collection, for all the materials would be available for specialists from all states.

During the Symposium a joint organizing meeting of the Commission on Manganes of the IAGOD and of the Project 111 "The Genesis of Manganese Ore Deposits" of the IGCP was held. There were made the reports on the work of the Commission and of the Project. It was decided to prepare a summarizing report on the results of the Project 111 and to start carrying out the new project of the IGCP "Global Correlation of Manganese Metallogeny to Paleoenvironments". Provisions were made to convene a session on geology and geochemistry of manganese in the framework of the VII IAGOD Symposium, Sweden, 1986.

The Symposium was a great international event which contributed to the intensive exchange of scientific information and to the consolidation of efforts of geologists and geochemists of the world in the field of geology and geochemistry of manganese and associated metals.

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