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IAGOD COMMISSION ON MANGANESE
IGCP PROJECT NO. 111: GENESIS OF MANGANESE ORE DEPOSITS

NOTES AND NEWS

ACHIEVEMENT AND SCIENTIFIC SIGNIFICANCE OF THE IGCP PROJECT No. 111: GENESIS OF MANGANESE ORE DEPOSITS

by
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The 2nd International Symposium on the Geology and Geochemistry of Manganese (25th IGC, 1976, Sydney) is to be considered as the start and the first result of the Project based on the activity of the IAGOD Commission on Manganese. The Monograph on the Geology and Geochemistry to be published (in English) in three volumes in 1978 can also be considered as a significant progress in the Project.

The lectures read at the Symposium and the papers to be published in the Monograph review not only the results and the progress in different fields of manganese research, moreover, they outline the directions of research, where for the sake of a successful progress a wide international co-operation is possible and necessary. The role of the Project is to promote and extend the active connections so far existing, drawing into the common work further institutions, groups and individuals interested in this field.

The progress made in different directions of manganese research could hardly be enumerated or even roughly outlined; it is only possible to point to the most interesting and promising topics with reference to works and authors already having a closer or looser connection to the Project.

Reviewing the huge scope of manganese research, it seems that special attention is focussed on the geology and genesis of manganese ore deposits on the continents, and on the origin and distribution of manganese and associated metals on the bottom of recent basins. Naturally, all the questions to be solved in these fields and those in general in the mineralogy and geochemistry of manganese, are closely interwoven.

Studies on the geology and genesis of manganese ore deposits on the continents are characterized by a multidisciplinary approach of the problems in their full complexity, taking into consideration the mineralogical, geochemical and petrological aspects, with special stress on the determination of the nature of the basins and the environments of deposition.

Research work carried out recently all over the world completed or modified our knowledge concerning the manganese ore deposits of different origin and age only to mention the major deposits as the huge manganese ore deposits in the Soviet Union, the Indian manganese ores or manganese deposits in Japan, the genetically very interesting manganese deposits in Brazil, Australia, Gabon, Ghana, which are very promising from the viewpoint of further research work.

Detailed studies of major manganese deposits, the studies of the protores and their weathering products as well as the investigations of the effect of metamorphism and the metamorphic mineral assemblages etc., considerably enlarged our horizon in this respect.

The thorough consideration of the conclusions of these extensive researches propounds, however, questions and ambiguities worthy of further study in the Project. Thus, it would be useful to study the genetical processes of phosphorite-manganese oxide associations for the sake of a better understanding of the behaviour of associated phosphorous (apart from the formation of apatite) in manganiferous sediments during metamorphism. Furthermore, there is no satisfactory explanation for the fact that important deposits of braunite and manganese oxide-silicate rocks are present in association with carbonaceous rocks or that graphite is present in an oxide-silicate assemblage (Guiana Shield, South America and Marau, Brazil, resp.). Likewise, a very interesting question: how the presence of high-temperature manganese oxides of lower valences as hausmannite, jacobsite, braunite, bixbyite may be interpreted in orebodies without any sign of metamorphism, as it was raised by Professor Supriya Roy, Leader of Panel I.

Very active and successful researches are presented also in the study of distribution of manganese and associated metals on the bottom of recent basins including the lakes, deep-seas and shallow-seas, in close conncetion with studies of problems of mineralogy and geochemistry of manganese and associated metals.

Wide-ranging investigations were carried out to study the submarine volcanism at spreading centers as a source for metalliferous deposits. Results suggest that the ferromanganoan active ridge sediments are only to a small extent due to the leaching of oceanic rocks or deposition from ordinary sea water, and a hypothesis was rendered probable by a lot of data that emanations of deep-seated origin, probably rich in CO_2 are carriers of Fe, Mn and other elements.

The connection between mineralization and the subduction processes at convergent plate margins is also one of the thoroughly investigated problems.

The Transatlantic Geotraverse Project of the National Oceanic and Atmospheric Administration discovered the TAG Hydrothermal Field in the Mid-Atlantic Ridge where hot springs enriched in various metals are apparently discharging from the sea floor and depositing a solid layer of nearly pure manganese oxide. It was established that types of metal deposits occurring in oceanic crust formed by sea floor spreading occur only along oceanic ridges where conditions are favourable; the distribution of localities is presently unknown.

It was demonstrated by a regional geochemical reconnaisance survey of marine sediments in the Southwest Pacific that the composition of these sediments shows a wide variability, and, in an area associated with a belt of earthquake epicenters, metal values higher than average were observed.

The progress raises at the same time the directions of further researches.

The concise programme in general terms, elaborated by Professor David S. Cronan, Leader of the Subdivision 3b aims to evaluate the influence of submarine volcanism on the composition of manganese nodules and encrustations, particularly its role in determining their regional compositional variability throughout the World Ocean. Therefore, it is proposed to investigate the chemistry of concretions from known volcanic areas in order to define characteristics which can be assigned to submarine volcanic activity. As the correlation part of the work nodules and encrustations from possibly volcanic areas should also be examined and compared with those from the known volcanic areas to see if they show any characteristics which would enable an assessment of volcanic influence on them to be made. Similarly, it would be of importance to investigate the relationship between hydrothermal submarine metalliferous sediments and associated ferromanganese oxide encrustations to see if chemical correlations between them are possible.

The aims of the Subdivision 3c are closely connected with those of the formerly mentioned Subdivision and the CCOP/SOPAC manganese programme. These aims may be summarized according to DR. G. P. GLASBY, Leader of Subdivision 3c as follows: the distribution and geochemistry of manganese nodules throughout the Pacific Ocean show that the most important problem to be tested is the role of biological productivity and transport in controlling the abundance and metal contents of manganese nodules. Areas of low metal content nodules in the Southwest Pacific associated with low biological productivity should be compared and contrasted with areas of high metal content nodules in the equatorial North Pacific associated with high biological productivity in order to asses whether the metal contents of the nodules are diagnostic of the environment of deposition, and in particular, the productivity of the overlying water. There are many interesting problems to be investigated *e.g.* the occurrence of bottom currents and submarine volcanism and the palaeoenvironment in and between fracture zones and the role of these factors in nodule formation; a comparison of manganese nodules and their associated sediments in the North, Equatorial and South Pacific in order to test the symmetry of distribution of carbonate, siliceous ooze and red clay sediments across the Equator. Of particular importance here is the exact relationship between the nodules of highest abundance and Cu-Ni content and the belt of highest productivity in the equatorial zone.

Scientific task and objectives of Subdivision 3d are shortly comprised by DR. PETER A. RONA, Leader of the Subdivision as follows: the objective is to study processes of concentration of manganese and other transition metals at oceanic spreading centers and to determine the distribution of concentrated metal deposits related to oceanic spreading centers. The approach is interdisciplinary, utilizing geological, geochemical, and geophysical methods to develop an understanding of metal deposits as the product of the total system active in oceanic spreading centers. The research covered by this subdivision includes aspects of the geologic setting, crustal structure, tectonics, petrology, thermal regime, oceanography, geochemistry of solid, liquid and gaseous phases, and other subjects relevant to the processes of concentration of metals at oceanic spreading centers and exploration of metal deposits in oceanic crust.

It may be concluded that the basic problems of manganese researches *i.e.* the origin and distribution of manganese are closely connected with the aspects of plate tectonics, and that it would be advisable for the IGCP Project No 111, the NOAA Project, the CCOP/SOPAC Manganese Programme, the IUGS Commission on Marine Geology and for the U.S. Inter-University Manganese Nodule Project to combine their forces to approach the solution of the problems mentioned, equally important from both a scientific and and economic viewpoint.

A number of works dealt in recent years with the origin, conditions of formation, chemical and mineral composition of iron-manganese nodules, concretions, encrustations in shallow water basins, in lakes and in shelf basins. Numerous observations in terrain and results of laboratory experiments suggest that accumulation products are initially formed as amorphous colloidal phases and that selective chemosorption and autocatalytic effects play an important role in the formation of the iron-manganese concretions. It was pointed out that the alternation of iron- and manganese-rich layers is the consequence of the seasonal fluctuations in Eh and pH, because the change of the redox conditions in the lake results in a change in the position of the reducing zone in the sediment.

Considerable progress was made in the interpretation of formation mechanism of the deep sea iron-manganese nodules. Some differences may be seen among the different mechanisms suggested which partly may be due to differences in physico-chemical conditions and chemistry of environments, the activity of microorganisms, the bottom current velocity at the site of deposition, etc.

It is generally agreed that initial deposition of hydrous ferric oxide precedes deposition of ferromanganese oxides on different types of nuclei. This hydrous ferric oxide phase was identified by recent investigations both in laboratory products and deep sea iron-manganese nodules as δ'-FeOOH, an unstable modification which may be transformed into goethite.

Explanation of the formation mechanism of iron-manganese nodules is possible only by inorganic processes. It is assumed that the initially precipitated manganous hydroxide (on the active surface of hydrous ferric oxide) may be at least partly oxidized, and precipitation by adsorption of additional Mn^{2+} from sea water may be proceeded. The autocatalytic oxidation of "10 Å manganite" results in a partial or complete loss of the 10 Å basal structure and associated water layers.

It is worth mentioning that a critical review of x-ray diffraction of nodules shows that the actual evidence does not support all of the evaluations and conclusions of the present literature. So, it is proposed that the phase previously named as "10 Å manganite" should be re-named as buserite. Furthermore, the synthetic experiments in laboratory lead to the conclusion that Mn in colloidal solution in waters will be present — at least as the first phase that can be detected — in form of extremely finely dispersed γ-MnOOH. The question may arise whether or not the nodules are formed in a secondary cycle where the initially precipitated γ-MnOOH is mobilized by reduction and reprecipitated in contact with aerobic waters on an active surface of hydrous ferric oxide. This hypothesis shows a close relation in some respect with an other formation mechanism outlined below.

According to an other mechanism, deposition by precipitation of iron-manganese oxides directly from sea water does not play an important role in the formation of iron-manganese nodules, since Fe and Mn is derived from the buried ooze where reduction reactions proceed. Carbonate complexes of iron and manganese migrate upwards into the upper part of the bottom ooze and at the interface of ooze and sea water $Fe(OH)_2$ is formed and oxidation processes — without participation of iron bacteria — lead to the formation of δ'-FeOOH. Contrary to the iron, manganese is wholly or partly precipitated by bacterial activity. Relics of bacteria as *Metallogenium* and *Siderocapsa* were found in the nodules studied.

It seems that some further questions may arise regarding the identification of manganese minerals of the nodules which may be solved by systematic and comprehensive study of formation, composition, structure, and reactions of oxide-hydroxides of manganese and iron under laboratory conditions on the one hand, and in natural environments on the other hand as it is recommended by DR. R. GIOVANOLI, Leader of Panel II, stressing the importance of investigation of processes which lead from Mn^{2+} ion to manganese sediments in order to establish — where this is not already done — which mineral species (solid phases) exist under given conditions and the importance of studies on reactions of laboratory products under controlled conditions in order to approach step by step the naturally ocurring systems. Problems in identification of manganese oxide minerals are probably due to the poorly crystallized character of the different phases. Consequently, the identification of finely dispersed manganese oxid-hydroxide phases by different methods is also of importance not neglecting the study of how the particle size and shape and other possible interfering factors (intergrowth, order-disorder phenomena, non-stoichiometry) influence the powder diffraction pattern.

Mineralogical studies and geochemical investigations form an integral part of most research project in the entire field, however, in spite of the progress made recently compiling a synopsis of all important criteria for the determination of the most important manganese oxides and hydroxides, there are still problems in nomenclature and recognition of manganese ore minerals, and also in recognition, description and interpretation of textures in ores — as it was raised by Professor Ronald K. Sorem, Leader of Subdivision 3c — which must be resolved before geologists can be sure that they know how others would interpret the features and minerals they discover. Therefore, it is necessary to encourage uniform standards for optical and x-ray, IR, thermoanalytical etc. studies, and to try to establish formats for presenting data so that findings from all parts of the globe can be compared with ease.

A number of works stress the importance of the role of microorganisms in the genesis of manganese accumulations both in the formation of lacustrine ferromanganese ores and deep sea manganese nodules. Manganese fixing bacteria were described in a Cretaceous chert and the extensive photomicroscopy and scanning electron microprobe study suggests that the bacterium *Metallogenium personatum* described in recent lacustrine sediments had had close analogues on the deep sea floor throughout much of geologic time.

The detailed study of the role of microorganisms in accumulation of manganese is very important because the oxidation of Mn^{2+} due to bacterial activity can take place under such physico-chemical conditions wherein it could not be expected merely by chemical reactions, furthermore, the rate of biogenic oxidation of Mn^{2+} catalyzed by microorganisms is several orders higher than that of chemical processes involved in autocatalytic oxidation.

* * *

The start of the IGCP Project No 111, as it was mentioned, can be traced back to the Sydney Symposium – keeping in mind, of course the work, lasting for about one and half a year, resulting in the International Symposium on Manganese, and collecting the material for the Monograph. The start and the preparation were alike really based upon a wide international distribution of work, and we are convinced that the common efforts experienced in the organisation work will also appear in the scientific work based upon an even distribution of the tasks bringing good results. Here mention should be made of the detailed programme to be outlined in the near future, their realisation, furthermore, of research training and technological transfer serving the vital interests of the developing countries.

The Report is based mostly on the contributions submitted to the 2nd International Symposium on the Geology and Geochemistry of Manganese, which represent the latest results in this research field as well as on the preliminary short programme proposals of Leaders of the panels and subdivisions, respectively. The Project leader would like to express his gratitude to all contributed to the compilation of this Report.

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The Project leader expresses his sorrow that because of the restrictions on Bibliography he could not cite many important papers, what the authors will surely understand.

APPENDIX

Measures of IGCP Project No 111 achievement in addition to scientific results

1. The scope of the Project No. 111 includes the study of metalliferous sediments in the recent basins from the Atlantic to the Pacific, and that of the manganese ore deposits on the continents, therefore, the Project can really count on a global intercontinental interest.

The distribution of countries among continents wherefrom contributions were submitted to the 2nd International Symposium on the Geology and Geochemistry of Manganese is as follows: Europe: six countries with 37 contributions; America; two countries with 11 contributions; Asia: three countries with 6 contributions:

* Papers denoted with asterisk will be published in 1978 in the Monograph: Geology and Geochemistry of Manganese by the Publishing House of the Hungarian Academy of Sciences in co-operation with the Schweizerbart'sche Verlagsbuchhandlung Stuttgart, FRG. These papers were abstracted in 25th IGC Abstracts, Volume 3, Sydney, 1976.

Africa: one country with 1 contribution; Australia and New Zealand with 4 contributions.

At present, scientists of 20 countries expressed their willingness and intention to collaborate within the Project joining to the different panels and subdivisions, respectively. The distribution of countries among continents is as follows: 12 countries from Europe, 3 from America, 2 from Asia, 1 from Africa as well as Australia and New Zealand, although according to the Geological Correlation Number 5, and the personal information from the IGCP Secretariat merely 13 IGCP National Committees announced so far officially their participation in the Project No. 111.

2. It may be supposed that the participation in the Project will promote the communication among scientists within the single regions, countries, too. It can rely on a greater group of scientists to collaborate in the Soviet Union, India, the USA, Brazil, Australia, New Zealand, Japan, the Federal Republic of Germany, France as it may be predicted from the announcement of scientists of different countries concerning their participation.

3. As to the role of the Project, it may be considered as an accelerator and catalysator, so to say, regarding the manganese research all over the world.

4. An interest in the Project should be shared not only by countries with manganese deposits of economic importance, having at the same time research possibilities of high level and a well trained staff of experts, but developing countries, for whom the fact of being included in the organized international cooperation can be a considerable help in exploration of manganese deposits, production, instrumental investigations, training specialists etc. But the Project calls as well specialists from countries which although have no important manganese deposits but can considerably contribute to manysided investigation with modern instrumental methods and evaluating the data and undertaking the organisation of courses, seminars keeping in line with the interests of developing countries.

5. The latest results in different aspects of manganese researches are comprised in the Monograph. It is hoped that it will be of worth for transfering the knowledge to scientists in developing countries and on the other hand the Project Staff will try with all means to initiate the developing countries, which have manganese ore deposits, to share the common work in a greater number than at present. Furthermore, it is planned to look for the possibilities of organizing seminars, courses for the experts of developing countries.

6. In the Monograph a comprehensive paper will be published on the essential data of the most important manganese oxide-hydroxide minerals. The work is to be continued in order to work out international standards for manganese ore minerals and ore textures.

7. The final and detailed programme denoting the subject areas and the way of collaboration between scientists of different countries participating in the common work will be discussed and approved in August 1978 at the IAGOD Commission on Manganese-IGCP Project No. 111 Meeting to be held in Snowbird, Alta, Utah, USA, during the Fifth Symposium of the IAGOD.

8. The Project can be a link with the NOAA Project, the CCOP/SOPAC Manganese Programme as well as with the US Inter-University Manganese Nodule Project, the IUGS Commission on Marine Geology, and last but not least the IAGOD Commission on Manganese who launched this Project.