GEOLOGY OF KUROKO DEPOSITS

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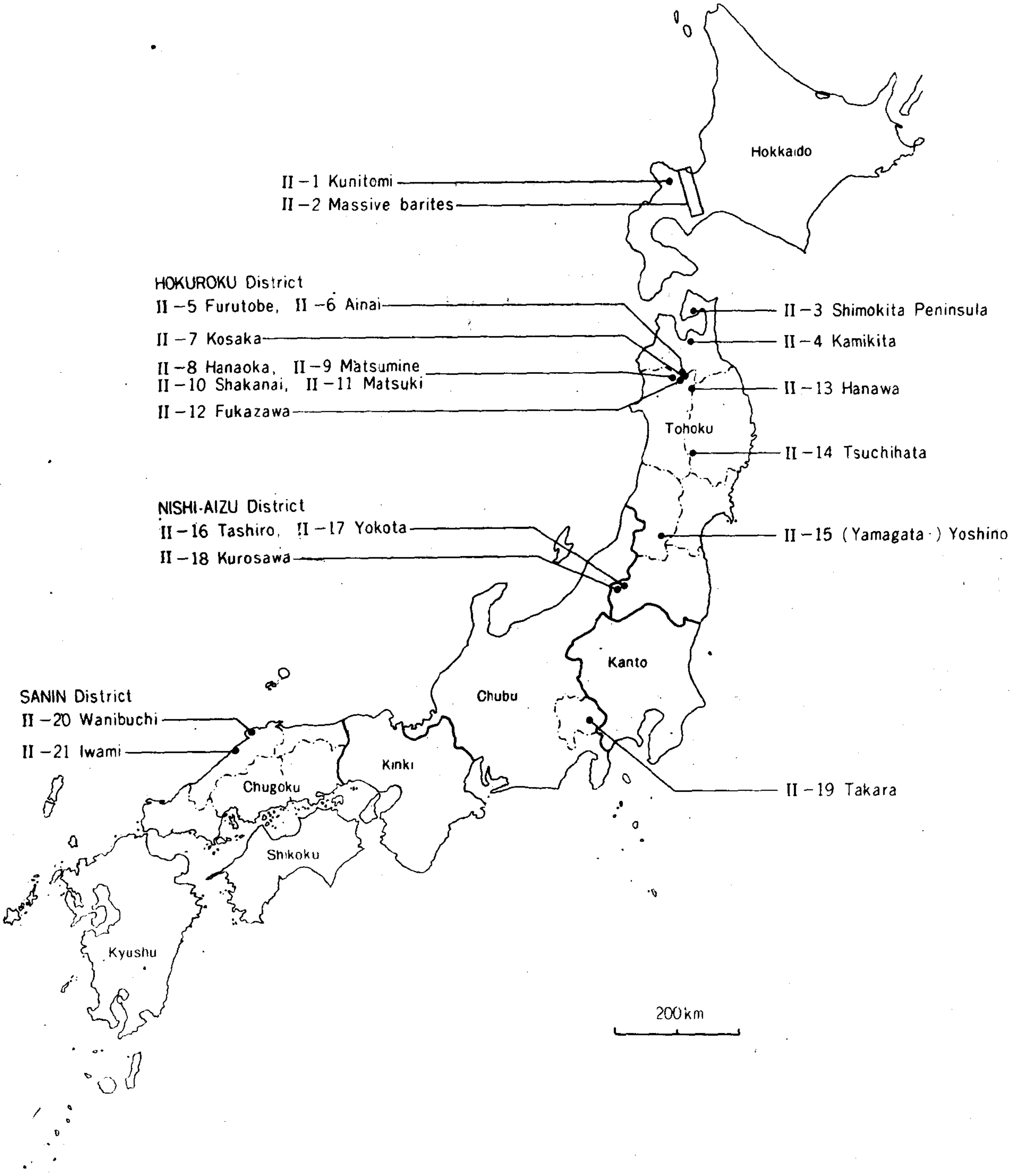
This issue is dedicated to

Takeshi HIRABAYASHI (1872–1935)
Takeo KATO (1883–1949)
Ryoichi OHASHI (1888–   )
Manjiro WATANABE (1891–   )
Kameki KINOSHITA (1896–1974)
and other pioneers

in the studies of Kuroko deposits



Geographic index for the papers in Part II

Editor's Preface

During the last decade, the demand for an international publication dealing comprehensively with the geology of the Kuroko deposits became increasingly strong with the progress of studies related to these deposits. Such a volume would undoubtedly be of great use for Japanese geologists as well as for foreign geoscientists. The preparation of an edition of such nature had been often discussed among the members of the Society of Mining Geologists of Japan, but no action had been taken because of linguistic difficulties.

The studies of Kuroko deposits have made striking progress during the last two decades, mainly because of the active exploration and investigation carried out by the mining industry and government agencies which resulted in the discovery of several large blind orebodies. Consequently, a large number of papers dealing with various aspects of these deposits have been published recently. Serving as the editor of *Mining Geology*, the periodical journal of the society, for several years, I found that there wes enough material to edit a volume of the nature described above. Thus the publication of this volume was planned in early 1972 and after recruiting the help of my colleagues, the work was underway.

The main scope of this publication is to bring together the available geological and mineralogical data in one volume, so that individuals can make their own interpretations of the Kuroko deposits. About a half of the papers have appeared in *Mining Geology* in Japanese, but they have been greatly revised in this volume with up-to-date information. The remainder is published for the first time in this volume. Papers such as those discussing physicochemical limitations on the formation of the Kuroko deposits have not been included, because these have already appeared in English in other journals (e.g., KAJIWARA, 1973b; SATO, 1973).

This volume consists of three parts. Part I defines precisely what we call Kuroko deposits, outlines their distribution and discusses their geological setting in the whole country as well as in two selected important regions. Part II describes the geology of the Kuroko and allied deposits. More than twenty mines are selected and listed from north to south (see previous page). Part III includes both new papers on specific subjects and some review papers specially prepared for this volume. Brief summaries of the geology, mineralogy and geochemistry of the Kuroko deposits are included within some of the papers in Parts I and III. The reader is also referred to the following recent English papers in other journals: MATSUKUMA and HORIKOSHI (1970), AOKI et al. (1970), TATSUMI and WATANABE (1971), CLARK (1971), TATSUMI et al. (1972), KAJIWARA (1973a, b), and LAMBERT and SATO (1974). A complete bibliography is available in the very recent summary publication in Japanese by WATANABE (1973).

* * *

It should be noted that there are some diversities in the usage of technical terms related to the Kuroko deposits. It is recommended that the terms "Kuroko deposit" and "Kuroko-type deposit" are used as outlined by T. SATO in this volume (p. 1–2), although these are used in slightly different ways in some other papers in this volume and *Mining Geology*. A typical Kuroko deposit (Kuroko deposit of T. SATO) may contain a whole sequence of geological units from the uppermost ferruginous chert and/or barite layers down through Kuroko (black ore) and Oko (yellow ore) beds, Sekko-ko (gypsum ore) bed or body, Ryukako (pyrite ore) and Keiko (silicious ore) bed or body, to the root zone of Keiko body or vein-type orebody. The Kuroko and Oko are by far the most important economically. They are bedded in shape and massive in texture.

The term massive is generally used for both designating texture and shape of ores and rocks in the Japanese literature. The terms network and stockwork may be used synonymously for texture, but some Japanese geologists define network texture as being more akin to veins. The typical Kuroko deposit may be divided into the upper bedded part and the lower root part. Most Japanese geologists prefer a syngenetic hydrothermal model for the bedded part, while a replacement model for the root part. In short genetic discussions like English abstracts of *Mining Geology*, the genesis of the bedded part may be discussed without specifying it. The terms essential, accessory and accidental are used for fragments contained in volcanic rocks. The usage is based on the definition of the late Professor Hisashi KUNO. Rhyolite (or pumice) fragments of the brecciated lava dome rhyolite or ore-horizon tuff for example may be called essential, and those of the basement Paleozoic slate are called accidental.

The usage of the Roman alphabet (Roomaji) in spelling Japanese proper nouns can be confusing even to the Japanese. Long vowels are common but the indication is often ignored. They are sometimes indicated by a line placed above them (e.g., Ōdate, the name of a Japanese city), by doubling the vowel (e.g., Oodate), or by inserting the letter "h" (e.g., Ohdate). The letter "h" should not be inserted between two vowels, because it would cause an incorrect pronounciation. Accentuation of Japanese words is very ambiguous and is usually ommitted in Roomaji transcript.

Japanese words normally written in Chinese characters (Kanji) can often be transcribed in more than one way (e.g., Nippon and Nihon, both mean Japan; OZAWA and OSAWA, name of a person; Takizawagawa and Takisawagawa, name of a formation). In these examples, frictive and plosive sounds are replaced by normal sound. Generally speaking, the Roomaji transcript of Japanese words is phonetic. All the vowels (a, i, u, e, o) should be pronounced as they are in German, except for the doubled vowels. Each vowel should be pronounced properly even in the case of the German "Doppelvokale" or "Diphthonge" (e.g., A-i-na-i, name of a mine; A-ni-a-i, name of flora; Ō-u, name of a mountain range).

* * *

Throughout the editorial period of about two and a half years, much time has been spent in clarifying the English expression of all the manuscripts, and nearly half of the forty-one papers had to undergo extensive revision or complete translation from Japanese, which delayed publication by about one year. My hope is that we did not change the original meaning in the course of this editing, and I wish to apologize for the delay to those authors who submitted their papers in rather complete form at the early stage.

I am deeply obliged to Dr. Y. SEKINE, executive secretary of the society for his encouragement and the authorities of the Society of Mining Geologists of Japan for their pertinent decisions, which made the publication possible. Valuable advice on the contents of this publication was given by Professor T. TATSUMI and Dr. E. HORIKOSHI of the University of Tokyo, and Dr. Y. KAJIWARA of Tokyo Kyoiku University, to whom I wish to express my sincere gratitude. I was fortunate to have a visiting geologist, Dr. I. B. LAMBERT of the Baas Becking Geobiological Laboratory, Canberra, at the Geological Survey of Japan during the early stage of editing, and he kindly reviewed nearly one-third of the manuscripts.

My last but not the least appreciation is reserved for all the authors who cooperated in this work, and of course the major credit of editing goes to my colleagues of the editorial board. It is my pleasure to acknowledge their encouragement and painstaking work throughout the editorial period without which this volume would not have been born. Administrative assistance by Mrs. K. SHIBATA and Miss Y. ONODARA of the society is also appreciated.

Kawasaki, Japan — Shunso ISHIHARA
July 30, 1974 — Editor

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Color Plates

Plate I Common ores and unusual occurrence of ores from Kuroko deposits

I–1. Kuroko (black ore) from the Shakanai No. 5 deposit at 257.5 mL. Estimated grade, 2.4% Cu, 23%Pb, 36%Zn and 26%S. Courtesy of the Shakanai mine. Photographed by Y. MASAI (×0.7)

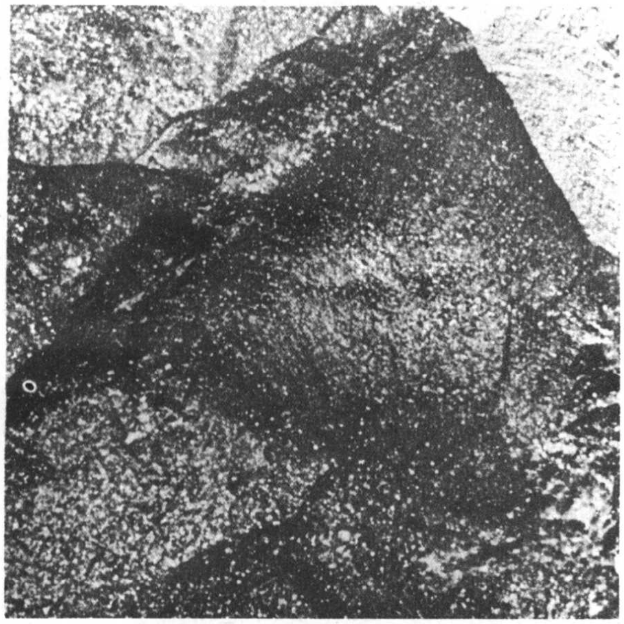
I–2. Oko (yellow ore) from the Shakanai No. 4 deposit at 307.5 mL, S. 47. Estimated grade, 5.5%Cu, trace Pb, 0.2%Zn and 33%S. Courtesy of the Shakanai mine. Photographed by Y. MASAI (×0.5)

I–3. A pillow like Kuroko with compositional banding, which is a sort of fragmental ore. The matrix is strongly argillized pumice tuff. Shakanai No. 1 deposit, No. 3 cross cut. Photographed by S. ISHIHARA (×0.1)

I–4. Fragmental Kuroko bed of the Kaminosawa No. 2 deposit, Kamikita mine, showing slumping of a large Kuroko block. Slightly oxidized. Photographed by S. ISHIHARA (×0.1)

I–5. Bornite-betechtinite-magnetite balls occurring in barite-hematite-quartz layer at the uppermost part of Daikokuzawa-Nishi deposit, W7–N7, 2ssL, Furutobe mine. Photographed by T. MATSUKAMA (×0.1)

I–6. Polished surface of laminated Kuroko from the uppermost part of the Daikokuzawa-Higashi deposit, 3 mL–N10.5, Furutobe mine. The top dark part is the hanging wall basaltic tuff; glittering thin layer is galena (and ferruginous quartz) layer. The black ore here is dominant in chalocopyrite and pyrite (yellow). Dark gray band is sphalerite. Photographed by T. MATSUKUMA (×1.5)



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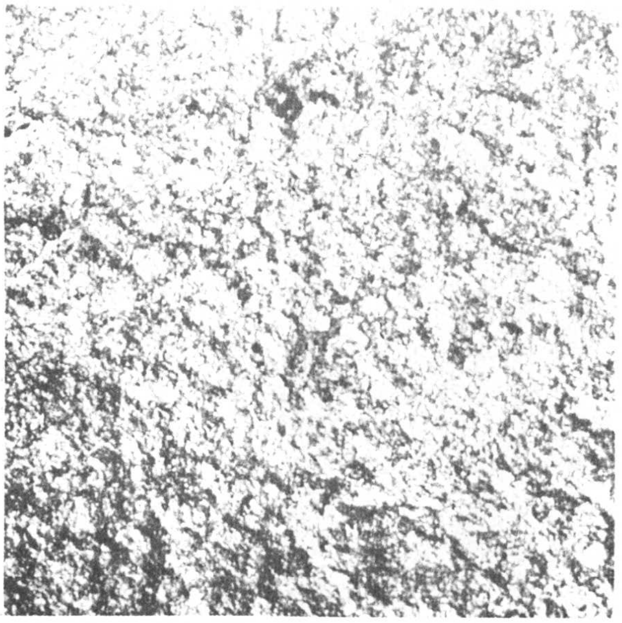

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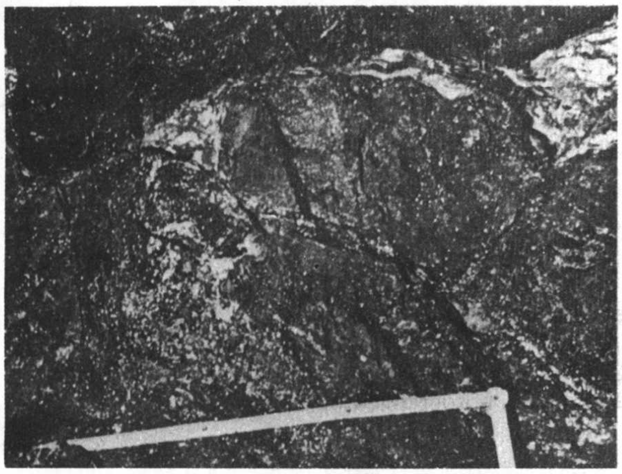

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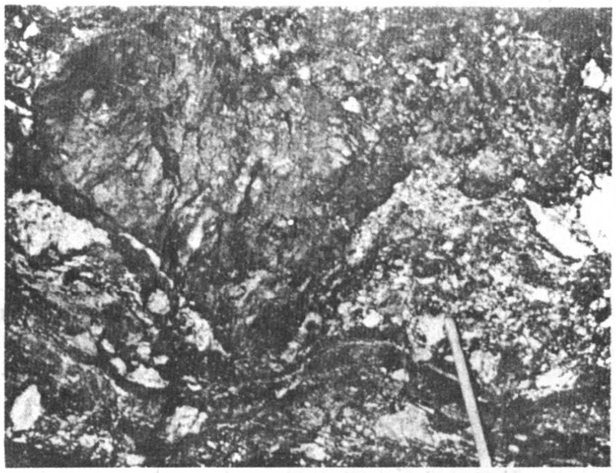

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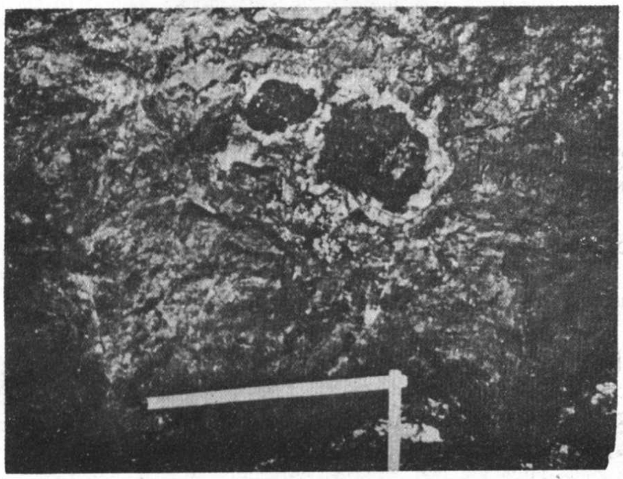

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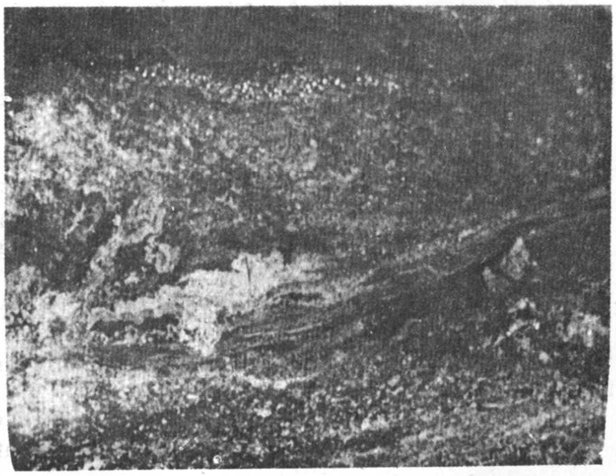

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Plate II Microscopic occurrence of ore-forming minerals from Kuroko deposits

II–1. Kuroko consisting of rosette-like growth of galena (white), sphalerite (light gray) barite (black needle). Uwamuki No. 4 deposit, Kosaka mine. Photographed by T. MATSUKUMA ($\times$120)

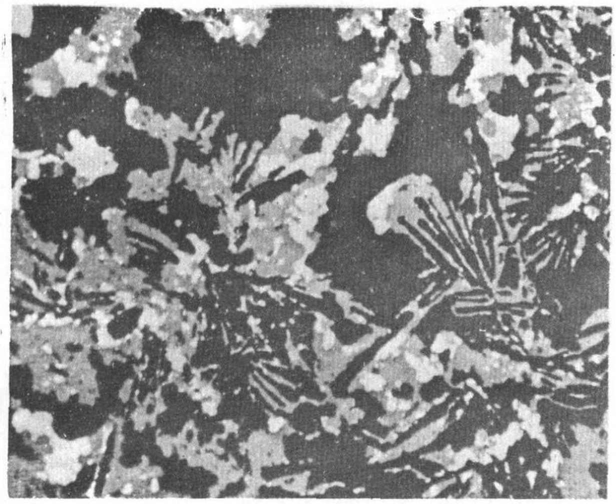
II–2. Kuroko consisting of galena (white), tetrahedrite (light gray), sphalerite (dark gray), chalcopyrite (yellow) and sericite (black). Uwamuki No. 4 deposit, MR–576. Photographed by T. MATSUKUMA ($\times$110)

II–3. Pellet-type colloform pyrite occurring in the Kuroko zone of the Uwamuki No. 1 deposit, L25. Photographed by T. MATSUKUMA ($\times$140)

II–4. Etched figure of colloform pyrite and chalcopyrite cut parallel to the growth axis. Yellow band, chalcopyrite; white band, pyrite. Dark, strongly etched part within the chalcopyrite bands consists of minute grains of pyrite. From the uppermost part of Kuroko zone of the Shakanai No. 1 deposit. Etched by conc. HNO_3. Photographed by T. SATO ($\times$ 20)

II–5. Tennantite (bluish green) occurring with chalcopyrite (yellow) and galena (white). Dark gray, sphalerite; black, mostly barite. A high grade copper ore from the Uchinotai-Nishi deposit, L 130, Kosaka mine. Photographed by T. SATO ($\times$80)

II–6. Betechtinite (cream), bornite (brown) and micrographic galena (white) found in some balls in the barite-hematite-quartz layer of Plate I–5. Photographed by T. MATSUKUMA ($\times$470)



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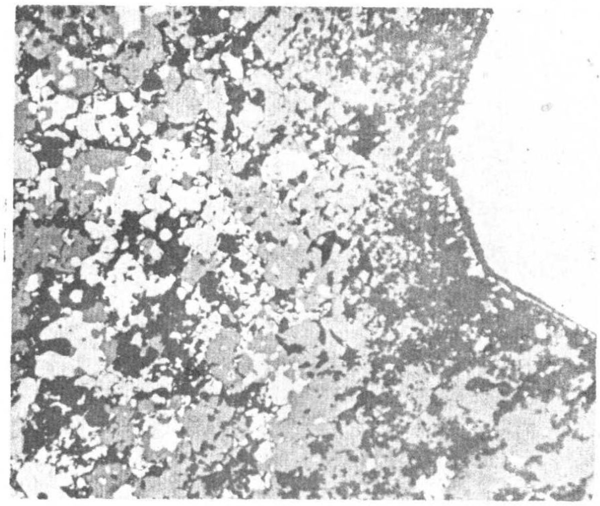

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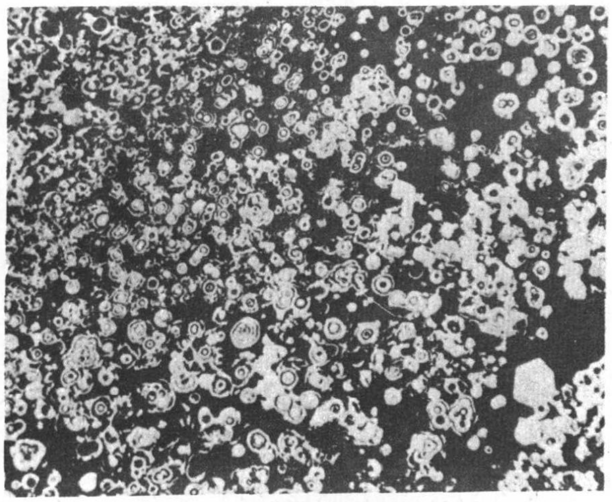

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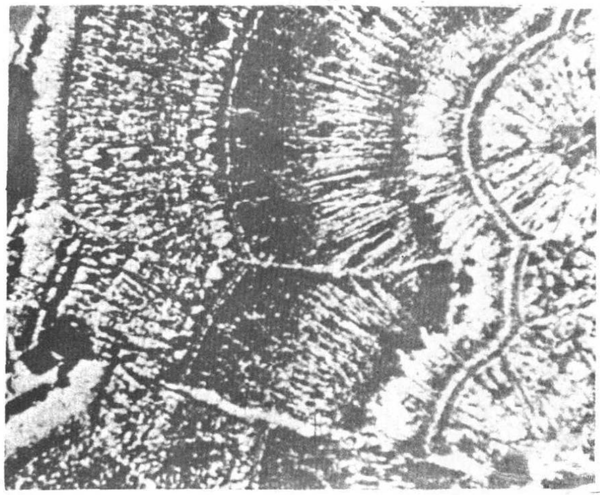

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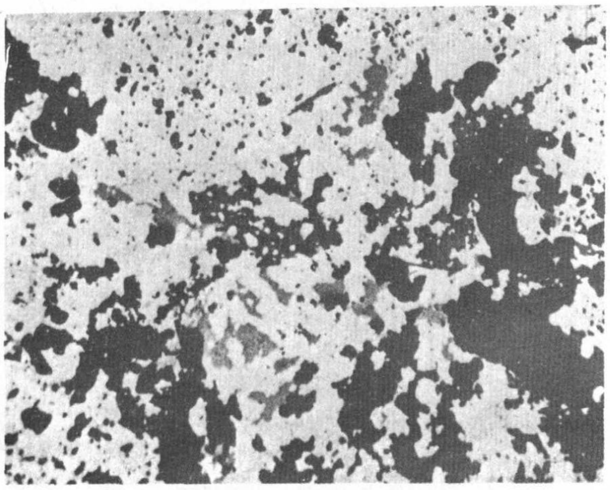

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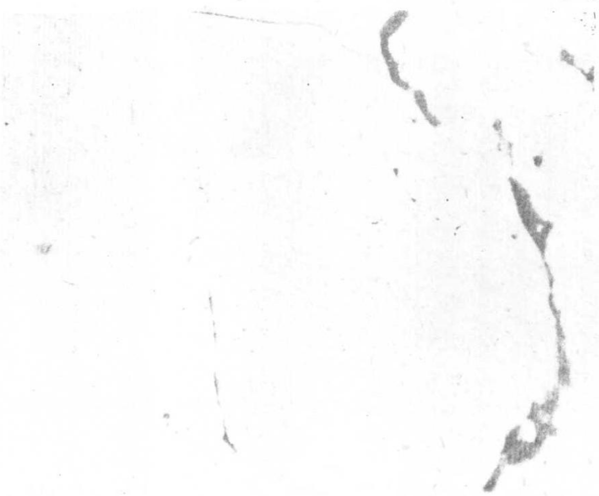

II–6

CONTENTS

PART III SELECTED TOPICS

INDICES

Distribution and Geological Setting of the Kuroko Deposits

Takeo SATO*

CONTENTS

INTRODUCTION

The Japan Sea side of the Japanese islands forms a specific geologic province characterized by thick volcanic and sedimentary piles resulted from subsidence and subsequent violent submarine volcanism in the Miocene. This province is called the Green Tuff Region because the volcanics show a characteristic greenish color as a result of diagenetic and hydrothermal alterations. Numerous Kuroko deposits occur in this region together with vein-type base metal and Au–Ag deposits. Their distribution, however, is by no means uniform both in time and space.

The present article attempts to describe the general features of the Kroko deposits and their geological environments, and also to clarify the relationship between the formation of Kuroko deposits and other geological events involved in the Green Tuff "Orogeny".

DEFINITION AND CLASSIFICATION

The Kuroko deposit is generally defined as a stratabound polymetallic sulfide-sulfate deposit genetically related with Miocene felsic volcanism (e.g., MATSUKUMA and HORIKOSHI, 1970).

Features common to many of the **typical Kuroko deposits** are;

(a) intimate association with submarine felsic volcanics of Miocene in age;

(b) economic or sub-economic grades of Cu, Pb, Zn, Ag and Au, and abundant occurrence of Ba- and Ca-sulfates;

(c) occurrence of stratiform or lenticular ore bodies that are concordant with the surrounding sediments.

Mineral assemblages and mineral zoning are very similar among many typical Kuroko deposits. A schematic cross section of the deposit is shown in Figure 1. In the stratiform ore body, the upper half is rich in galena, sphalerite and barite (black ore), while pyrite and chalcopyrite are dominant in the lower half (yellow ore). Underlying the stratiform ore body is the stockwork ore body, which is characterized by disseminated and network mineralization of pyrite and chalcopyrite distributed in an irregular funnel shape in felsic lavas and pyroclastics. The stockwork ore is generally strongly silicified and is called siliceous ore. Boundaries between these ore bodies and between the stockwork ore body and the unmineralized volcanics are gradational, while the boundary between the stratiform ore body and the hanging wall sediments (tuff and/or mud) is sharp. Small lenses or thin beds of ferruginous chert often occur directly overlying the stratiform ore body or in the tuff of the hanging wall. Gypsum and/or anhydrite occur as lenticular or irregular mass between the stockwork and the stratiform ore bodies or adjacent to the stratiform ore body.

It is not uncommon to find galena, sphalerite and barite as the dominant constituents both in the stratiform and the stockwork ore bodies. This is usually the case for relatively small ore deposits enclosed in pyroclastics. In such cases, amounts of pyrite and chalcopyrite also gradually increase downward.

Sulfides to sulfates ratio and size of the stratiform ore body relative to the stockwork ore body are variable from deposit to deposit. It is not uncommon that only a trace of sulfide mineralization is observed in and adjacent to a large gypsum ore body, or that the stratiform ore body is very small or absent above a productive stockwork ore body. These extreme cases are included in the Kuroko-type deposits.

The **Kuroko-type network deposits** are those deposits which in many respects resemble the stockwork ore body of the typical Kuroko deposits (i.e., shape of the ore body and the mineral composition of ore), but are associated with little or no stratiform mineralization. They have intermediate features between the typical Kuroko deposits on one hand and fissure-filling veins on the other. Thus discrimination of Kuroko-type network deposits from typical Kuroko deposits and from non-Kuroko-type network deposits, and further from fissure-filling veins are rather arbitrary and does not seem to be essential. Kuroko deposits and fissure-filling deposits in the Green Tuff Region are likely to have close genetic relationship as suggested by their side-by-side occurrences at the Yoichi mine, Hokkaido, the Komaki mine, northeastern Honshu, and many other localities.

The **Kuroko-type gypsum deposits** differ from the typical Kuroko deposits only in that they contain little or

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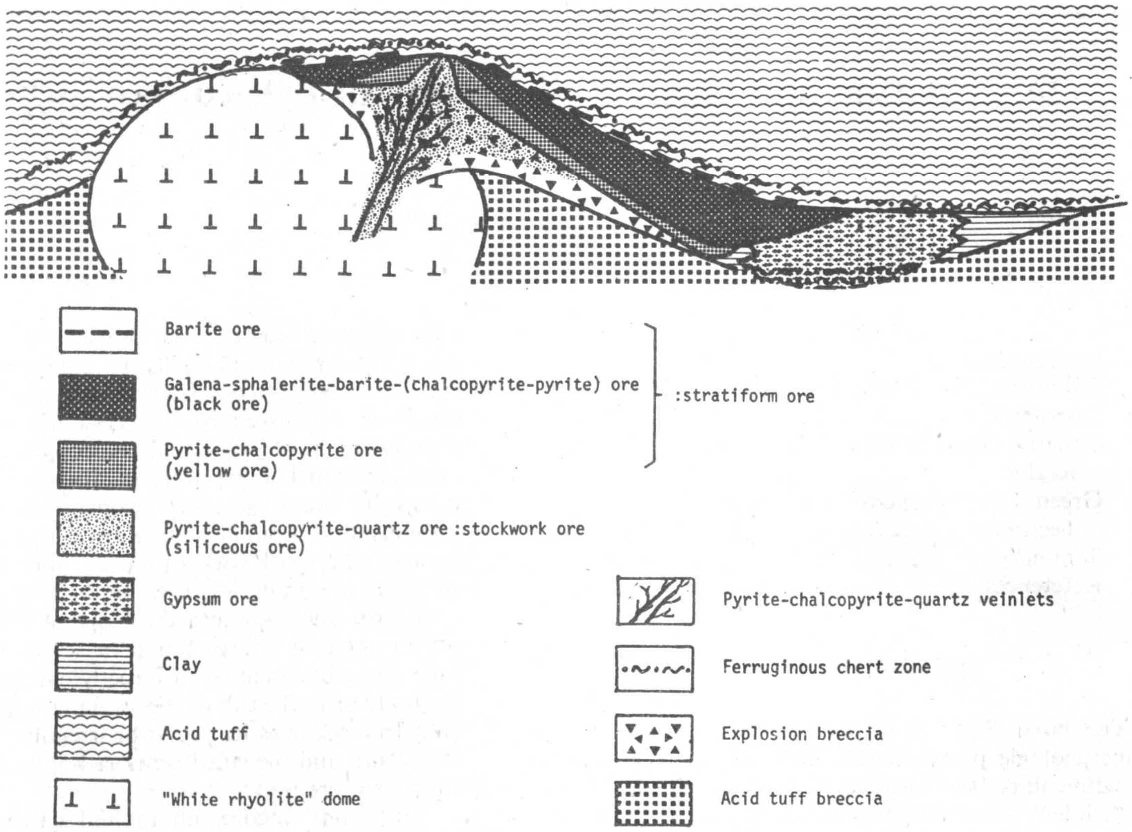

Fig. 1. Schematic cross section of a typical Kuroko deposit.

practically no sulfides. In this case again, discrimination between them is arbitrary. At the Wanibuchi mine, southwestern Honshu and the Yonaihata mine, northeastern Honshu, for example, small lenticular masses or thin beds of galena-sphalerite-barite ore occur at the uppermost part of the gypsum ore bodies, but they are generally classified into the Kuroko-type gypsum deposit because the sulfide ores are not economic in scale.

The **Kuroko-type barite deposits** consist essentially of barite, which occurs both in stratiform and stockwork orebodies without any considerable amount of sulfide minerals. A few deposits of this type occur in Hokkaido.

The **Kuroko-type pyrite-gold deposits** occur in Hokkaido, Izu Peninsula and southernmost Kyushu. The common characteristic features of the deposits of this type are pipe-like shapes of ore bodies, rare occurrence of sulfide minerals other than pyrite and/or marcasite and association with kaolinite-diaspore-native sulfur-(allunite) in the altered zone surrounding the ore bodies. Occurrence of small amounts of luzonite and/or enargite at upper levels of the deposits is also common to many deposits of this type.

The gold to pyrite ratio varies considerably from deposit to deposit. At the Oage mine, in northeasternmost Honshu, for example, several pyrite masses occur around dome-shaped dacite, but their gold content is not economic. At the Akeshi and Kasuga mines, southernmost Kyushu, on the other hand, gold occurs as electrum in highly silicified tuffs with only a trace amount of pyrite. Gold occurs mainly as tellurides at the Date mine, Hokkaido and the Suzaki mine, Izu Peninsula.

Deposits of this type are believed to have formed under near-surface or even subaerial conditions (e.g., Kinoshita, 1944) and to be genetically related to the Kuroko deposits.

DISTRIBUTION

Figure 2 shows the distribution of all Kuroko mines, including typical and related types, with past record of production of any amount.

In eastern Hokkaido only a few minor Kuroko deposits are known. This region is characterized by important occurrences of mercury and gold-silver deposits. In western Hokkaido, on the other hand, several Kuroko mines such as Kunitomi, Yoichi, Meiji and Toya, have histories of cosiderable metal production. Kuroko-type barite deposits are known only in this region. The Date mine is a gold-pyrite deposit.

In the Green Tuff Region of northeastern Honshu, occur not only most of the important Kuroko deposits but also many of the most productive vein-type deposits in Japan. As shown in Figure 2, the more important occurrences of the Kuroko deposits are clustered in several districts.

The Shimokita Peninsula District includes the Abeshiro, Taisho and Nishimata mines, where many small typical Kuroko ore bodies were exploited. The ore bodies at the Oage mine contain negligible amount of base metals and were mined for pyrite.

The Hokuroku District, covering only about 500 km², is by far the most important Kuroko field, including