講 演 要 旨*

層状鉱床の2，3の問題点

鉱床部　竹田　　英夫

北部北上山地岩泉帯のマンガン鉱床

吉井　　守正

岩手県九戸郡軽米町・大野村および山形村付近の一帯には，層状のマンガン鉱床が密集する．この地域の地質とマンガン鉱床との関係について2,3考察を試みる．

地質は，吉井・吉田(未公表)によると岩泉帯に属し，三畳紀～ジュラ紀の一連の地層が整合関係で重なる．それらの層序とおもな岩相は下位から順につぎのとおりである．

木沢畑層（1,500m＋）　チャートおよび粘板岩
間木平層（250～1,000m）　砂岩・礫岩および粘板岩
沢山川層（100～700m）　玄武岩および同質火砕岩
安家層（100～800m）石灰岩
関層（2,500m）　粘板岩チャート互層
合戦場層(1,000m) アーコース質砂岩およびチャート

化石として木沢畑層から三畳紀のコノドントが（村田・杉本，1971)，また安家層から六射サンゴおよび海綿が産出する．

この地域の一般走向はN30～60°W，傾斜は60～85°Wを示し，一見同斜構造に見えるが，地域のほぼ中央にはNNW-SSE方向に延び南へゆるやかに沈む軸をもつ背斜構造が認められる．これに平行な断層が多数あって，地層のくりかえしがみられるほか，ENE-WSW方向の断層による水平方向のずれもあって，地質構造は複雑化している．

背斜の東側と西側では岩相変化が認められ，東側では玄武岩とその火砕岩および石灰岩体が厚く発展するのに対し，西側ではそれらが少なく，アーコース質砂岩が発達する．

これらの中生層に古白亜紀の花崗閃緑岩が貫入し，地域の東部で広い分布を示すほか，地域内に小岩体が点在する．これらによる熱変成作用のため，中生層を構成する岩石には，黒雲母が生じている．黒雲母が認められる範囲は，地域東半部の大部分に及び，西部では西方へ向かって非変成地帯が広がっている．

マンガン鉱床の分布を眺めてみると，鉱床はいずれもチャート層中に層状に胚胎され，大多数の鉱床が関層とその上位の合戦場層に含まれる．関層中のマンガン鉱床のあるものは，一定の層準の範囲に限って胚胎されている．地域内に多数の鉱床胚胎層準があるようにみえるのは，地層のくりかえしによるものである．

この地域のマンガン鉱床は，産出する主要鉱石により，ブラウン鉱を主とする鉱床と，ハウスマン鉱や菱マンガン鉱を主体とするいわゆる“炭マン”の鉱床に分けることができよう．前者は，地域東半部すなわち背斜の東側に分布し，後者は背斜の西側に分布するように見える．両者のほとんどは同じ関層中に胚胎されるものである．

一方，この地域の熱変成度と，マンガン鉱床の鉱石種との関係を比べてみると，黒雲母が生じている地域内の鉱床は，ブラウン鉱を主とする鉱床が，非変成地帯では，“炭マン”を主とする鉱床がそれぞれ分布する．すなわち，おもに関層に胚胎されるマンガン鉱床の東西における鉱石種の差異は，熱変成度に起因する可能性がある．

葛巻構造線を境にして岩泉帯に隣接する北部北上帯では，宮古以南を除いてマンガン鉱床の数はごく少なく，2，3にとどまる．北部北上帯では岩泉帯と同様にチャートおよび粘板岩を主体とするが，石灰岩が少なく，火山岩類も一部の地区を除いてごく少ない．時代も石炭紀(？)～二畳紀と岩泉帯の時代と異なっている．

マンガン鉱床に富む岩泉帯の地質環境を考えてみると，砂岩に富み，リーフ性の石灰岩も存在し，北部北上帯に較べればやや浅い海で，また火山活動も盛んであったと推定される．

マンガン鉱床のこのような堆積環境との成因的関係は今後の課題であろう．

黒鉱鉱化作用の一モデル

鉱床部　佐藤　　壮郎

A Summary of Evidence for the Bacterial Formation of Stratiform Sedimentary Sulphide Deposits

Ian B. Lambelt*

Introduction

The Middle Proterozoic Mount Isa, Hilton

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* 昭和48年1月25日本所において開催．

* Baas Becking Geobiological Laboratory, Canberra Australia.

and McArthur River Pb–Zn–Ag deposits (Australia), many of the Upper Proterozoic Copperbelt Cu deposits (Africa) and the Permian Kupferschiefer Cu–Pb–Zn deposits (Germany) are important examples of very large sulphide deposits which occur as conformable laminae within sedimentary strata. Many geologists who have investigated such deposits consider that they were formed by bacteria, which reduced sulphate to sulphide and possibly also concentrated metals from dilute solutions.

These deposits are very fine grained when they have not been metamorphosed, and they are typically associated with carbonaceous, high potash shales and dolomitic rocks. They are not closely associated with volcanic activity–the Australian deposits contain some fine tuff beds suggestive of terrestrial volcanism some distance away, but no volcanic activity of any sort has been recorded at the times of formation of the Kupferschiefer or Copperbelt deposits. This is one of the main reasons that volcanic sulphur or high temperature inorganic reduction of sulphate are not usually considered to have been instrumental in the formation of these deposits.

All deposits appear to have formed in elongated, fairly shallow continental seas which may or may not have had openings to the ocean. It is common that several deposits formed penecontemporaneously at different places along each sea.

It is difficult to prove that bacteria were important in the formation of these deposits, but there is a lot of circumstantial evidence in favour of this. My purpose here is to summarize these various lines of evidence.

Evidence for bacterial origin

1. Environments of ore formation appear suitable for bacteria. The sedimentary host rocks for these stratiform ores accumulated slowly in near shore basins containing considerable amounts of organic matter. Similar environments at the present day are characterized by high levels of activity of sulphate reducing bacteria. Metals are not toxic to the bacteria when they are introduced into the environment at rates below the rates of sulphide production; in fact, metals can enhance bacterial activity.

2. Possible fossil bacteria have been recognized in the ores. It is probable that sulphate reducing bacteria evolved well before the Middle Proterozoic, which is the age of the oldest recorded stratiform sedimentary deposits.

Structures possibly representing fossil bacteria can be discerned under very high magnification in the organic matter of the host sediments. Also, minute pyrite framboids with organic 'skins' may have precipitated within the bodies of bacteria. However, there is not universal agreement on the interpretation of these structures.

3. Pyrite is formed by bacteria in many present day sedimentary environments. Pyrite has been recorded in small amounts in many recent sediments and it is generally acknowledged that this was bacterially produced. A. number of instances of probable bacterial precipitation of Cu have also been described.

4. Bacterial metal sulphides can be formed easily in the laboratory. Sphalerite, galena, pyrite and digenite, which are common in various stratiform deposits, have all been synthesized bacterially in the laboratory. More complex sulphides such as chalcopyrite and bornite have not been produced bacterially to date, but they could have formed in nature by reaction between copper ions and bacterially produced iron sulphides, or between Fe^{++} ions and bacterially precipitated copper sulphides.

5. Sulphur isotopic ratios are in accord with bacterial sulphate reduction. The sulphide minerals of the stratiform sedimentary ore deposits are characterized by very variable δS^{34} values, with a general tendency to S^{32} enrichment. Such isotopic distributions suggest their sulphur was of bacterial origin.

6. Rates of bacterial sulphate reduction appear to be adequate for ore formation. It is probable that a lower limit for the rates of formation of stratiform sedimentary ore deposits is provided by the rate for accumulation of fine grained sediments in euxinic basins. The Black Sea basin is a well-studied example of an environment where such sediments have been depositing in recent times; the average rate here is approximately 1 cm of unconsolidated sediment every 100 years. The metal sulphide laminae in the ores could have formed relatively rapidly whilst the detrital sediments were coming in at normal rates. This would mean that the ores could have accumulated significantly faster than the Black Sea sediments. An upper limit for their deposition rates should be provided by the metalliferous deposits in the Atlantis II Deep under the Red Sea. These were precipitated (inorganically) at an average rate of about 1 cm every 25 years and contain relatively little intercalated detrital sediment.

Calculations based on these limiting values indicate that the rates of sulphur production necessary to form the stratiform sedimentary sulphide deposits being discussed here are considerably lower than the maximum values that have been measured in natural environments.

7. Bacteria can concentrate metals from dilute solutions. Sulphate reducing bacteria can effect very large concentrations of metals from dilute solutions. Concentrations by factors as high as as many thousands have been recorded in laboratory experiments. Whilst this is not nearly enough to form economic metal deposits from normal seawater, given solutions with about 1 ppm metals, it appears feasible that bacteria could concentrate these to ore grades.

Conclusions

The various lines of evidence presented above are based on data obtained from investigations in modern day sedimentary basins and in the laboratory. If it is reasonable to extrapolate these data back as far as Proterozoic times, it can be concluded that it is very likely that the stratiform sedimentary sulphide deposits formed as a result of bacterial processes. The environments of ore formation should have been very favourable for high levels of bacterial activity and the necessary rates of sulphide generation should have been within the capacity of sulphate reducing bacteria. The scarcity of such ore deposits in the geological column relative to the amounts of carbonaceous sediments probably reflects the rarity of adequate long term metal sources.

ノルエーレッケン地域の火山岩層序と鉱床

東京大学　堀越　　叡