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MINERALIZATION AND VOLCANISM IN BABELDAOB ISLAND, BELAU

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The Zn-Au hydrothermal ore deposits in volcanic rocks in Babeldaob Island, Republic of Belau (Palau), were discovered in the period of the World War II. However, the genesis for these ore deposits has not been discussed yet in detail. In this report, the Zn-Au ore deposits as well as volcanism and paleo-weathering, are geochemically studied to consider the environment of mineralization in the evolution of the Palau island arc system.

Babeldaob Island is composed mainly of the volcanic rocks and raised coral reef. The volcanic rocks erupted during Ecocene to Oligocene, and debilitated at late Oligocene. The weathering of the volcanic rocks is recognized under lignite formations of Miocene to Pliocene age (TAYAMA, 1952).

Volcanism in Babeldaob Island

The volcanic rocks of Babeldaob Island occur as lavas, agglomerates, volcanic breccias, tuff breccias and tuffs, with the composition of olivine basalt and hornblende bearing two pyroxene andesite, accompanied with clinopyroxene hornblende dacite. The geological occurrences, such as propylitic alteration and its stratigraphy, suggest eruption under submarine as well as on land. These volcanic rocks are grouped into four formations; Babeldaob Agglomerate (early Eocene), Aimeriik Agglomerate (late Eocene) and Almonagui Agglomerate (Oligocene) (TAYAMA and SHIMAKURA, 1937; TAYAMA, 1952).

The samples of the volcanic rocks were collected from the Babeldaob and Aimeriik Agglomerates. The samples were chemically analyzed using XRF for major elements, ICP-Mass and atomic absorption for minor elements, EPMA for mineral compositions, and others.

The SiO_2 contents of the volcanic rocks vary widely from 47% to 67%. The petrography and geochemistry of the fresh rocks show that two types of volcanism; low potassium olivine tholeiite rock series and calc alkaline rock series, are recognized in Babeldaob Island. Incompatible elements pattern normalized by N-type MORB, and REE pattern normalized by chondrite are shown in Fig. 1. The Palau volcanism is similar to those of the other island arc systems in the West Pacific region, especially to that of the Mariana island arc system (TATSUMI et al., 1983), and is characterized by the coexisting of two rock series in spite of the limited space and time of eruption: The patterns of Babeldaob Agglomerate are similar to those from back arc side of the other island arc systems (TATSUMI et al., 1983; YOSHIDA et al., 1995). On the other hand, the Aimeriik Agglomerate is similar to those in volcanic front zone. The coexisting of two kinds of volcanism in same area might be affected by the internal environments of steep subduction system.

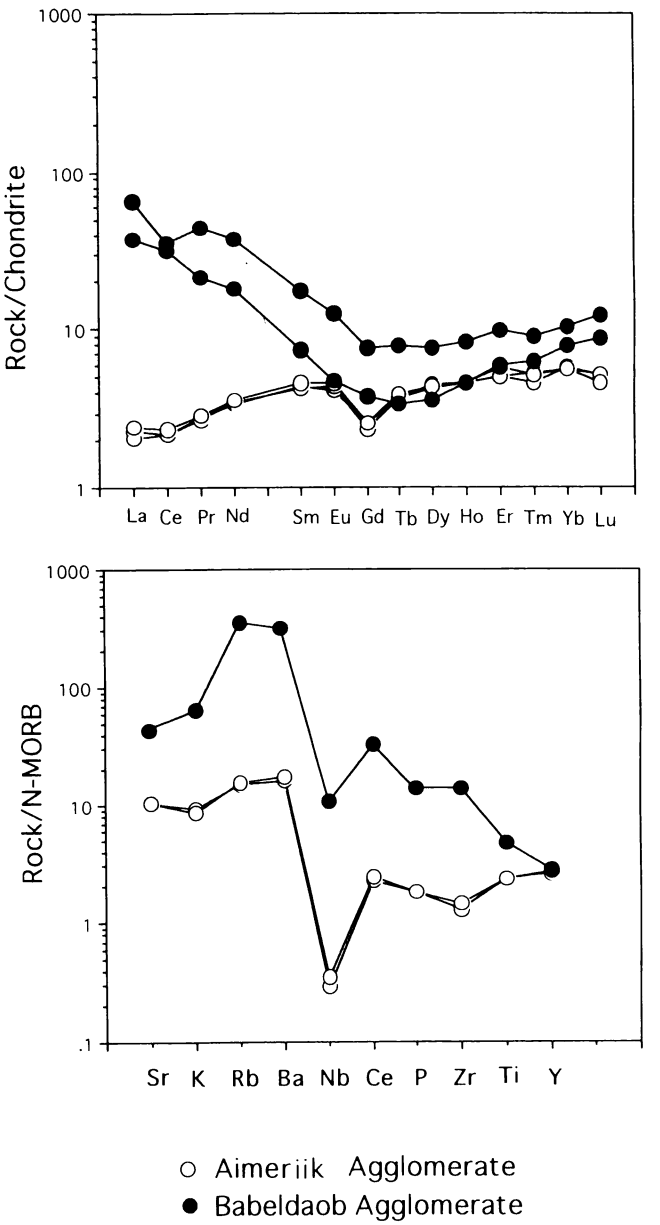

Fig. 1. REE pattern normalized by chondrite (above) and incompatible elements pattern normalized by N-type MORB (below) of the volcanic rocks from Babeldaob and Aimeriik Agglomerates in the Babeldaob island.

Zn-Au Mineralization in the Rois Malk Area

The Rois Malk Zn-Au mineralized area is located in Oikull, the eastern area of Airai State, and many argillic veins are observed on the surface. The country rock of the veins is

Babeldaob Agglomerate. MILLER et al. (1987) explored in this area. According to them, more than 100 mineralized and barren veins are distributed all over the area of 1 by 1.5 km in size. The volcanic rocks of Babeldaob Agglomerate have widely altered to propylite. The width of the vein is up to 2m, with the average of about 10cm. MILLER et al. (1987) pointed out that hydrothermal alteration in and near the veins was of neutral potassic type, similar to those of epithermal gold deposits in the other island arc systems. The rotated ores from Zn-Au mineralized veins are observed on the eastern coast of the area. Collected samples from the Zn-Au veins were studied under a microscope, a heating-cooling stage, and an EPMA.

Sulfide minerals are sphalerite, pyrite, galena, chalcopyrite, hematite, magnetite and electrum. These minerals well coexist with each others. In addition, MILLER et al. (1987) reported argentite, iodyrite, cerargyrite and native silver. The hydrothermal alteration are of propylitization, argillization and silicification.

Fluid inclusions are often observed in the sphalerite and quartz in the vein. All inclusions contain liquid and gas phases, but no solid phase. The liquid/gas volumetric ratio of the fluid inclusion in sphalerite is almost the same, but gaseous inclusions are occasionally observed. As shown Fig. 2, the filling temperatures of fluid inclusions of two phases in sphalerite range from 304 to 375°C, and many data concentrate in rather small range from 310 to 325°C with an average of 318°C. Tailing of distribution is recognized in the high temperature side. The tailing and existence of gaseous inclusion suggest that the temperature of the mineralization was about 320°C, and that the fluid temperature was near boiling point. The filling temperatures in quartz are from 255 to 337°C, which are lower than those in sphalerite. As boiling phenomena are not recognized in the fluid inclusions in quartz, the fluid inclusions might be formed from low temperature fluid at later stage. The salinity of fluid inclusions is from 4.5 to 8.8 wt% NaCl

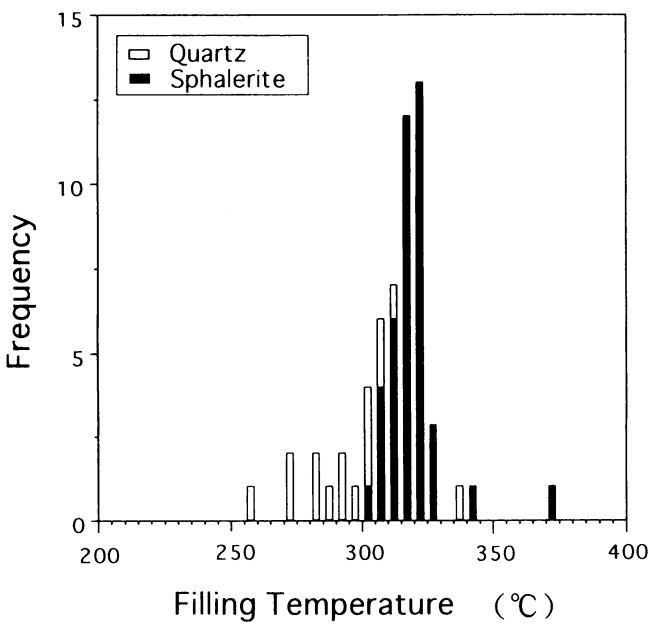

Fig. 2. Filling temperatures of fluid inclusions in sphalerite and quartz from the Rois Malk mineralization area.

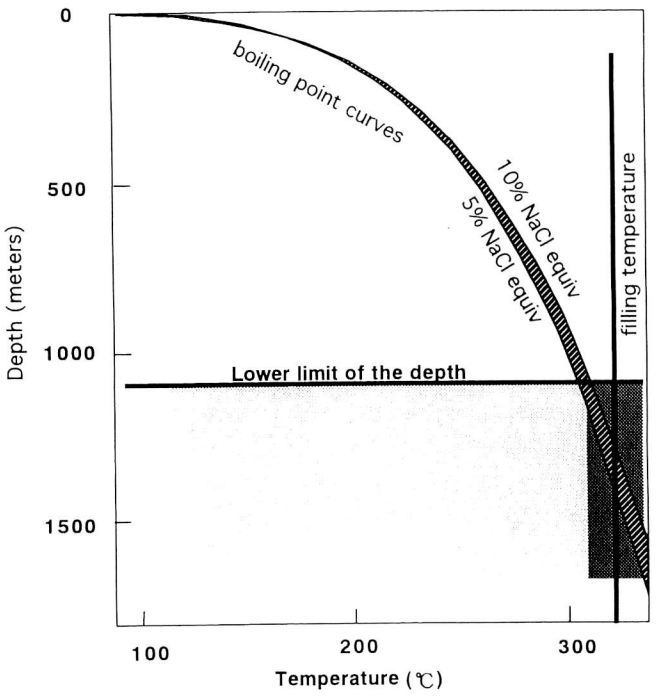

Fig. 3. Estimation of the depth of mineralization of the Rois Malk mineralization area, assuming the fluid boiling.

equiv. The results suggest that sphalerite and other associated ore minerals precipitated from the almost boiling brine at about 320°C, and that the depth of the mineralization was deeper than 1000m, as shown in Fig. 3. MILLER et al. (1987) described a few small hypabyssal dikes in the mineralization area. The ore solution might emanate from the magma of the hypabyssal dikes. However, the present data set might support the hypothesis that the hydrothermal solution was produced by sea water convection. For example, the salinity of fluid inclusion is near but always higher than that of sea water.

Sphalerite shows high transparency under a microscope and partial anisotropy suggests that the sphalerite contains wurtzite. The margin of sphalerite grain contains chalcopyrite diseases. Fig. 4 shows iron and copper contents of the sphalerite. The copper content increases with the increase of the iron content. Fig. 4 suggests that the detected copper is from chalcopyrite impurity, and that the sphalerite does not dissolve copper, essentially. FeS contents, subtractted the effect by chalcopyrite, vary from 2 to 3 mol%. The Au contents of electrum are from 77 to 84 atm %. Using the data of mineral assemblage, FeS content of sphalerite, and Au content of electrum, the environment of mineralization is predicted as Fig 5. As shown, f_{S2} of the ore solution might be about 10^{-8} and f_{O2} might be about 10^{-28}. These values are higher than those of the epithermal gold ore deposits in the island arc systems of the West Pacific region. The controlling factors of the environment will be discussed after getting the stable isotopic compositions (e.g. $\delta^{34}S$, δD and $\delta^{18}O$) in near future.

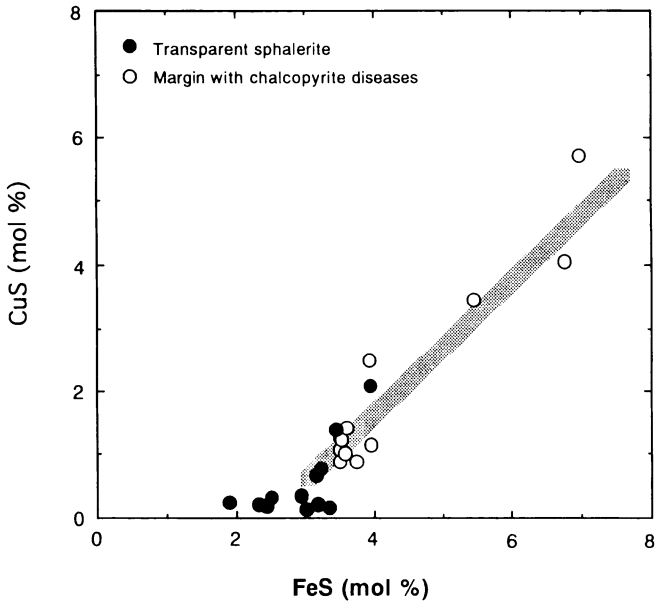

Fig. 4. Iron and copper contents of sphalerite from the Rois Malk mineralization area.

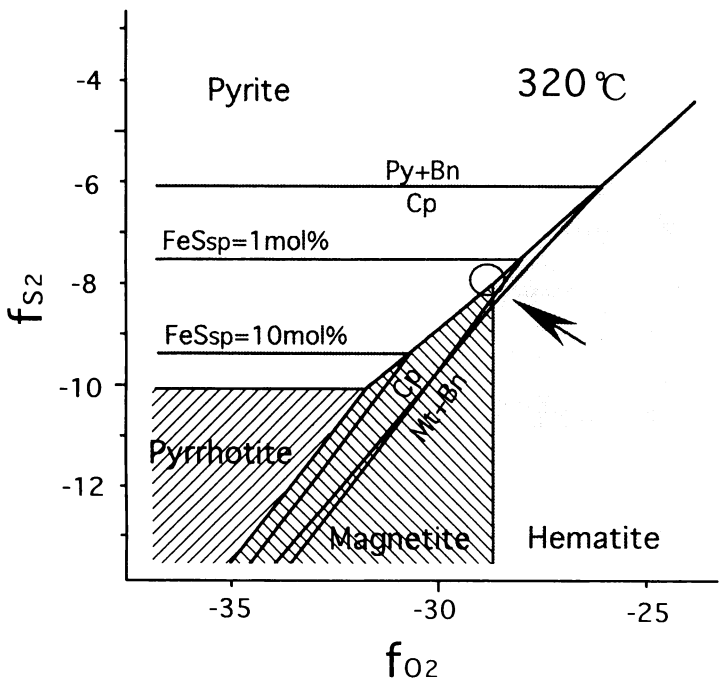

Fig. 5. Condition of the Rois Malk mineralization, predicted from the mineral assemblage and FeS content of sphalerite.

Lignite Deposits and Tectonic Evolution of the Islands

These volcanic rocks and mineralized veins are overlain by lignite deposits of Miocene to Pliocene, which occur sporadically in the marginal parts of Babeldaob Island. Kaolinite weathering on the Babeldaob Agglomerates is dominant below the lignite formation. Deposition of plant materials and acid-anoxic weathering have advanced in some lagoon pools.

Eruption of the volcanic rocks near sea level and the boiling temperature of about 320°C of the ore solution suggest the descending tectonics more than 1000 m after eruption of the volcanic rocks of Paleogene. The environment of this area has changed to ascending tectonics at the end of Paleogene. Such the large movement might not have been during Neogene. Seismological activity in present stage is very weak compared to the other island arc systems, and there has been no volcanism during Neogene and Quaternary. The Paleogene volcanism characterized by the coexisting of two rock series suggests the internal environments of steep subduction system. From these evidences, the discontinuity, such as a transverse fault, might be predicted between the Palau and Yap (and Mariana) island arc systems at the Paleogene -Neogene boundary.

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