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学位論文題目（英文）	モザンビーク、Tete 地域、Mugomo および Chifumbazi 金鉱床の地質と地球化学的特徴 - 鉱床成因の制約条件 (Geological and Geochemical Characteristics of the Mugomo and Chifumbazi Gold Deposits, Tete Province, Mozambique - Constraints on the Ore Genesis)
論 文 審 査 委 員	（主査）教授　Andrea Agangi （副査）准教授　高橋　亮平 （副査）教授　渡辺　寧 （副査）教授　大場　司

論文内容の要旨

The Mugomo and Chifumbazi gold deposits are located in the Chifunde District, Tete Province, northwestern Mozambique. The geology of the study area is composed of the Proterozoic Mualadzi Group comprising ultramafic metavolcanic rocks, quartzite, biotite-schist, Macanda Mafic Metavolcanics, conglomerate, and granitoid of the Furancungo Suite. The geological characteristics and metallogenesis of gold mineralization in the Tete Province are poorly understood. This study aims to describe gold mineralization and associated hydrothermal alteration in the Mugomo and Chifumbazi deposits on the bases of petrography, whole rock geochemistry, fluid inclusion, and sulfur isotopes.

The host rocks of the Mugomo deposit are metavolcanic rocks, biotite-schist, and quartzite, and they are cut by epidote and quartz veins and epidote-quartz-chlorite veins and veinlets. The host rocks of the Chifumbazi deposit are quartz-mica-schist (*i.e.*, meta-plutonic rock) overlain by gneiss, and the former is cut by quartz, quartz-carbonate (calcite, dolomite, and ankerite), and chlorite veins and veinlets. The veins and veinlets occur along the discordant fracture system within a Pan-African shear zone.

The metavolcanic rocks in the Mugomo deposit are composed mainly of plagioclase, quartz, and biotite, with secondary epidote, chlorite, and calcite, the biotite schist is composed mainly of biotite and quartz. The quartzite is composed of

quartz and minor plagioclase. In the Chifumbazi deposit, the quartz-mica-schist is composed mainly of quartz, plagioclase, biotite, and muscovite, with secondary calcite, ankerite, sericite, and chlorite, while the gneiss is composed chiefly of quartz, biotite, and opaque minerals. Hydrothermal calcite, chlorite, and sericite occur either as small veins and veinlets or as alterations replacing primary minerals.

The metavolcanic rocks of the Mugomo deposit have a narrow range of SiO_2 (69.5 –81.7 wt.%) and can be classified as rhyolite or dacite in composition using the classification diagram of Zr/TiO_2 vs. Nb/Y. The metavolcanic rock shows moderate concentrations of FeO_T (1.37-11.59 wt.%). The Al_2O_3 contents vary from 9.23 to 16.14 wt%, while the concentration of CaO varies between 0.44 and 6.44 wt.%.

The quartz-mica-schist in the Chifumbazi deposit has a SiO2 content (55.2- 72.4 wt.%), and it can be classified as rhyodacite or dacite which is almost equivalent to granodiorite in composition using the volcanic rock classification diagram of Zr/TiO2 vs Nb/Y. The quartz-mica-schist has moderate FeO_T contents (2.85-7.52 wt.%), Al_2O_3 contents from 12.6 to 20.0 wt%, CaO contents from 0.15 to 3.73 wt.%, as well as negative anomalies of Nb, Sr, P, Eu, and Ti, and positive anomalies of Rb, Ba, K, and Pb in primitive normalized plots. On the other hand, the metavolcanic rocks of the Mugomo deposit are depleted in Rb, Nb, P, Eu, and Ti.

The ICP-MS whole rock data from the Mugomo deposit compositions indicate up to 2 ppm Au, 16 ppm Ag, 281 ppm Cu,19 ppm Te and 87 ppm Pb which suggests that the main mineralization stage includes visible gold in pyrite disseminated in the metavolcanic rock. On the other hand, the quartz veins in Stage II of the Chifumbazi deposit include visible gold associated with pyrite and chalcopyrite. The whole rock compositions indicate up to 5 ppm Au, 30 ppm Ag, 8064 ppm Cu, 310 ppm Ni, 85 ppm Te, and 65 ppm Pb in the milky quartz veins.

Homogenization temperatures and salinity of fluid inclusions in quartz veins of the Mugomo deposit range from 200 to 430 ℃ and from 0.0 to 15.0 wt.% NaCl equiv., respectively, while those in Stage II of the Chifumbazi deposit range from 216 to 369 ℃ and from 0.7 to 15.3 wt.% NaCl eq, respectively.

The presence of shear zones is one of the important geological constraints for the formation of vein systems in the northern part of Tete province, as sulfides and gold are commonly found associated with quartz, quartz-carbonate, chlorite, and epidote veins.

Based on the geological setting, mineralogy, trace elements in quartz, fluid inclusions, and sulfur isotope signatures, the Mugomo and Chifumbazi deposits can be classified as orogenic type. Especially, the Chifumbazi deposit has distinct characteristics of orogenic gold mineralization, i.e., (i) orientation of veins structurally controlled by faults and shear zones, (ii) proximal sericite-chlorite-carbonate alterations, and (iii) presence of CO_2 in vapor inclusions of quartz veins.

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論文審査結果の要旨

The thesis submitted by the candidate Ms Francisco Cossa reports on a geological-geochemical study of gold-mineralized rocks at Chifumbazi and Mugomo, Tete province, Mozambique. Tete province is an area that is known to host numerous small-scale gold prospects that are locally mined and contribute to the local economy. However, the area remains largely underexplored, and its gold production figures and resources are largely unknown. The aim of this study is 1) to define the nature of the gold (vein, disseminated) and the associated hydrothermal alteration, 2) to define the ore minerals occurring with gold and their formation sequence, 3) to study the rocks that host gold at Mugomo and Chifumbazi, and 4) to understand the source of the mineralizing fluids in these deposits.

The study included field work and sample collection, followed by laboratory analyses, which were carried out mostly at Akita University personally by Ms Francisco Cossa, and to a lesser extent by a commercial laboratory.

The field observations identified a series of veins, some of which are mineralized, that are hosted in various metamorphic rocks belonging to the Meso- to Neoproterozoic Mualadzi Group and Furancungo Suite. The veins were then better characterized in microscope observations and classified based on their minerals (quartz, epidote, chlorite, carbonate, sulfides). The main ore minerals are pyrite, chalcopyrite, pyrrhotite and native gold, occurring in veins at Chifumbazi, or disseminated in the host-rocks at Mugomo. At Chifumbazi, the highest gold contents of up to 5 ppm were found in milky quartz veins, whereas at Mugomo, gold contents of up to 2 ppm were measured in metavolcanic rocks.

A petrographic and microthermometric study of fluid inclusions identified water-CO2 fluids at Chifumbazi, with variable salinities (0 – 15 wt. % NaCl equivalent) and homogenization temperatures around 200 – 360°C, and H2O-CH4 fluids (at Mugomo) with homogenization temperatures around 220 – 430°C and similar salinity.

Chemical analyses of the host-rocks were used to infer the setting of formation, and improve the understanding of the tectonic history that preceded ore deposition. The majority of veins have similar northeast-southwest orientation to the regionally observed structures related to the 590-560 Ma Zambesi Orogeny.

The candidate has made use of a wide array of techniques and analytical approaches, and has demonstrated sufficient technical proficiency. These range from observations and sampling in the field, to sample preparation techniques, to several types of laboratory analyses. The data obtained are to a large extent new and add significantly to the set of available data on the area. By taking Chifumbazi and Mugomo as study cases, the candidate has provided a detailed description of geological, geochemical and mineralogical characteristics of the gold deposits in the wider Tete Province area.