TECTONIC SETTING AND MINERALIZATION AT GABAL ABU HOUDEID AREA, SOUTH EASTERN DESERT, EGYPT.

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論　文　要　旨

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論　文　内　容　の　要　旨

Egypt is part of the highly complex orogenic belt of East Africa, which is comprised of the Arabian-Nubian Shield in the north and the Mozambique belt in the south. This complex tectonic setting led to the formation of several mineral deposits related to the Pan-African orogenic cycle. The Gabal Abu Houdeid area is located at the southern part of the Eastern Desert of Egypt, at the boundary between Egypt and Sudan. It is considered as the extreme northern part of the Hamisana shear zone, which is one of the major high strain zones of the Neoproterozoic Pan-African Arabian-Nubian Shield. This research reports the inter-relationship between tectonic setting and base-metal sulfide and invisible gold mineralization in the Gabal Abu Houdeid area, SE Egypt. This comprehensive study of the Gabal Abu Houdeid area includes integrated remote sensing and GIS studies, examination of field relationships, petrographic and geochemical analyses, and structural and tectonic investigation.

This thesis consists of seven chapters that discuss the different aspects of the research. Chapter 1 introduces the research background and significance of this study, presents the study area within the ANS tectonic context, and describes the methodology used.

Chapter 2 discusses the multispectral remote sensing (Landsat ETM+ and ASTER) image enhancement and interpretation. This methodology was implemented to determine, extract, and delineate the different litho-tectonic rock units and their related structures in the study area. The integrated image transformation methods include Principal Component Analysis (PCA), Band Ratioing (BR), and False Color Composites (FCC) on selective bands of the ETM+ and ASTER data. The data have been found to be scene-dependent, and complement each other in the identification of lithologic and structural features in different scales throughout the Gabal Abu Houdeid area.

Chapter 3 describes the geological characteristics of each rock unit cropping out in the Gabal Abu Houdeid area on the bases of the remotely sensed data, field relationships and the petrographic studies. The results reveal that the Neoproterozoic basement rocks exposed in the Gabal Abu Houdeid area consist of three main litho-tectonic rock units: mafic–ultramafic dismembered ophiolitic rocks, island arc-related metasedimentary-metavolcanic rocks, and syn- and post-tectonic intrusive rocks. The syn- and post-tectonic intrusives include granodiorite, gabbro, muscovite granite, and alkali feldspar granites.

Chapter 4 discusses the structural setting of the Gabal Abu Houdeid area through ductile and brittle deformational analysis. Four deformational events are distinguished in the Neoproterozic rocks. Event D1 is a pure compression stress regime with $\sigma 1$ stress axis trending NNW-SSE to N–S. It represents an early shortening event associated with the Pan-African thrusting, during which intra-oceanic arcs and plateaus were accreted. Event D2 is characterized by structures that developed under ENE-WSW compressional regime (shortening event), and is considered as the early stage of the second episode of collision within the Pan-African orogeny. Event D3 is transpressional deformation associated with E-W contraction and N-S extension. It is the main event that controlled the deformation along the Hamisana Shear Zone during the late stages of the collision between the East and West Gondwana in terms of escape tectonics. The D4 event is

interpreted as a post-orogenic extensional event manifested by E-W dextral strike-slip and dip-slip normal faults striking NNW-SSE to N-S and E-W, which began to occur after the emplacement of post-tectonic granites.

Chapter 5 examines the geochemical characteristics of each rock unit cropping out in the Gabal Abu Houdeid area in order to reconstruct or deduce the tectonic environment in which these rock units were formed. The Gabal Abu Houdeid ophiolites are identified as cumulates and non-cumulates, sourced from an enriched mantle with depleted-K and enriched-Ti, and related to a back-arc setting of oceanic tholeiite geochemistry. The island-arc related biotite schist and quartzites show geochemical characteristics typical of back arc sediments that originated from a blended felsic-mafic source. The geochemistry of the metavolcanic rocks shows basaltic composition derived from alkaline to sub-alkaline magma in arc and/or back arc settings. The magmatic activity in the Gabal Abu Houdeid area basement complex is represented by the formation of early syn-tectonic I-type granitoids (mainly granodiorites), post-tectonic gabbros and muscovite-alkali feldspar granites. The post-tectonic intrusive rocks, whether gabbros or younger granites, both indicate within-plate tectonic signatures.

Chapter 6 discusses the geological and mineralogical characteristics of the mineralized areas of the Gabal Abu Houdeid area based on the investigation of the geology, ore mineral assemblage, and structures in order to clarify the condition of mineralization and the inter-relationship between the tectonic setting and the mineralization from the point of view of deformational phases. The Gabal Abu Houdeid base-metal sulfide and invisible gold mineralization are restricted to the quartzite, which is considered as member of island arc-related metasediments. These quartzite bands are closely situated in a map-scale, NNW-SSE to N-S striking brittle-ductile shear zone and a NNW- trending brittle-ductile shear zone in the uppermost part of the HSZ. The base-metal sulfide mineralization is represented by two phases: an early mineralization phase that includes pyrite, pyrrhotite, argentite and invisible gold; and a late phase dominated by pyrite, galena, sphalerite, chalcopyrite, ± invisible gold and covellite. The gold associated with base-metal sulfide minerals in the Gabal Abu Houdeid area mostly occurs as invisible gold or submicrometer-size inclusions in pyrite. The early pyrite phase revealed the presence of trace amounts of Au (up to 8.33 ppm), which has higher Au content than the late-stage pyrite (up to 1.5 ppm). Structural controls on the Gabal Abu Houdeid mineralization have been documented at different scales. The exceptional geographic location of the Gabal Abu Houdeid within a major high strain belt zone of the Hamisana Shear Zonereflects the decisive role in the deformation history as well as the mineralization in the area. The structural interpretation of the quartzite bands and surrounding areas indicate that the base-metal sulfide and associated gold mineralization are mostly syn-kinematic and controlled by D3 transpressional deformation events, which in turn controlled the emplacement of syn-tectonic granitoid intrusions and related hydrothermal solution systems under ductile-brittle conditions.

Chapter 7 summarizes the previous six chapters and outlines the conclusions of this study based on the different analyses, data interpretation and integration. Tectonic evolutionary scenario for the Gabal Abu Houdeid area was proposed on the basis of the inter-relationship between lithology, structure and geochemistry aided by multispectral remotely sensed data. The integrated data suggest that the exposed rocks in Gabal Abu Houdeid most likely developed in a combined escape tectonic and back-arc tectonic setting. The back arc deformation is manifested by the ophiolitic slices obducted onto the island arc assemblage. Thrust, folding, and crustal shortening fabrics are observed and recorded through ophiolitic and island arc rock assemblages. The escape tectonics (post-dating the obduction) manifested by the transpressional deformation regime are superimposed onto the rocks and may be more or less contemporaneous to calc-alkaline magmatism expressed in the emplacement of syn-tectonic granites. The base-metal sulfide and associated gold mineralization are mostly syn-kinematic and controlled by the D3 transpressional deformation event.