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論文題目	3D geostatistical modeling and integration of lithology, physical properties and element contents for characterizing metal deposit in a seafloor hydrothermal vent area（岩相，物性，元素濃度の 3 次元地球統計学的モデリングと統合による海底熱水噴出域での金属鉱床の特徴抽出）		

As the world's population rises, demand of metals increases and requires ore production from deposits on land and seafloor areas. The search for valuable metal resources in deep seafloor is both inevitable and vital to accommodate the constantly increasing demand. Seafloor hydrothermal fields account for important source of economically valuable mineral deposits termed as volcanogenic massive sulfide (VMS) types. These deposits generally contain largest amounts of base metals such as Cu, Pb, and Zn and precious metals such as Au and Ag in some cases. Many countries demand strongly these mineral resources. However, due to the difficulties in surveys and sampling of subseafloor and high cost of drilling operations, spatial distributions of metal contents below the seafloor have not yet been clarified well. This PhD dissertation aims at not only specifying target areas where the occurrence of these mineral resources is likely to be expected but also shedding light on the transport and deposit mechanisms of those polymetallic sulfide elements in offshore active hydrothermal areas. For this purpose, a combination of data-characterization methods, such as principal component analysis (PCA) and k-means clustering, and spatial modeling techniques using conditional geostatistical estimations and simulations is applied to whole-rock geochemical data obtained by inductively coupled plasma-quadruple mass spectrometry (ICP-MS) together with lithologic log data by onboard visual core descriptions and X-ray diffraction (XRD) analyses from the Hakurei Site in the middle Okinawa Trough back-arc basin during the cruise CK16-05 (Exp. 909) in 2016 by D/V Chikyu. The primary goal is to construct plausible 3D distribution models for the contents of base and precious metals and lithotypes. This dissertation consists of the following seven chapters, which are intercorrelated and provide the bases to clarify the mechanisms of transport and deposit of polymetallic sulfide elements.

Chapter 1 is an introduction to summarize the content of this research with an overview of preceding, general geologic settings, VMS deposit features, unsolved problems, and motivation for understanding the mineralized zones and generation mechanisms of deposits. Chapter 2 is devoted to present the essential materials and methods to implement this research, which is composed of the geologic setting of the Hakurei Site, the characteristics and provenance of available data, data treatment, and statistical and geostatistical methods.

Chapter 3 examines the effectiveness of an estimation and two conditional stochastic geostatistical methods, ordinary kriging (OK), sequential Gaussian (SGSIM) and turning bands (TBSIM)

simulations, respectively, to clarify metal content distribution and locate mineralized zones by the uses of limited amount of metal content data at few drilling sites. Among these methods, TBSIM was proved to be the best method to achieve the goal of this research in the situation of sparse data. This finding plays a pivot role in the dissertation, and TBSIM is used to divide the model domain for increasing the pluri-Gaussian simulation (PGSIM) performance in Chapter 6. Chapter 4 employs TBSIM to clarify the spatial distributions of physical properties and the chemical elements of dominant constituent sulfide and sulfate minerals in the study area. These outcomes are essential to reveal the metal zoning and physical and chemical interactions with the zoning. In addition, Chapter 5 applies TBSIM alongside PCA of the whole-rock geochemical data to characterize the meaning of the first two principal components (PCs) by examining their loadings and PC values. The first parameter manifests the importance of each element in each PC, while the latter product aids to reveal the 3D distribution of main metal elements over the study area. This chapter Also discusses and highlights reversal relation between chalcophile elements, which represent the mineralized zones in the SMS system, and rare earth elements alongside yttrium (REY). Chapter 6 incorporates the results of Chapters 3 to 5 to extract the maximum information from the sparse drilling data and construct plausible 3D models of geochemical compositions and lithotypes. This goal is achieved by applying a combination of data-characterization methods using PCA, k-means clustering, TBSIM, and PGSIM. The constructed models successfully express the configuration and zonation in the study area with hydrothermal flow paths, which sheds light on hydrothermal circulation system and metal accumulation mechanisms. Furthermore, the models can show in detail inner structure of the stockwork and stratiform polymetallic massive sulfide layers with tens of meters below the seafloor. The approach proposed is demonstrated to be effective for geologic and mineralization modeling and preliminary exploration of seafloor hydrothermal deposits. Finally, Chapter 7 summarizes the concluding remarks, including the primary results from all chapters. Besides, important future works to advance seafloor VMS researches are introduced.