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Preliminary Geostatistical Modeling of Physical and Chemical Properties in a Seafloor Hydrothermal Vent Area in the Mid-Okinawa Trough

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1. Introduction

Hydrothermal fields account for important source of economic mineral deposits called Volcanogenic Massive Sulphide (VMS) types. These deposits correspond to major sources of Zn, Cu, Pb, Ag, and Au and significant sources of Co, Sn, Se, Mn, Cd, In, Bi, Te, Ga, and Ge (Galley et al., 2007). Seafloor hydrothermal vent areas have been important as a source of this type deposits.

The study area is a hydrothermal field on the Iheya North Knoll located roughly 150 km NW of Okinawa Island. The Okinawa Trough is a back-arc basing located in East China Sea between the Ryukyu Arc-Trench system and the Eurasian continent (Tsuji et al., 2012; Miyoshi et al., 2015). It is under extensional stress and its sea floor is covered with about 2 km-trick sediments (Letouzey and Kimura, 1986; Tsuji et al., 2012). Figure 1 depicts the drilling sites implemented by JAMSTEC Strategic Innovation Promotion Program (SIP; red points) as well as the locations of an Integrated Ocean Drilling Program (IODP) Expedition 311 (green points) that collected samples with shallow drillings up to the 60 m depth. To compensate the lack of information, the reports of Integrated Ocean Drilling Program (IODP) Expedition 311 (Takai et al., 2011) were used for this study, providing more details. According to the reports, the drilling C9015A is nearby active chimneys.

Having the data of electrical resistivity, this study aims to describe how the spatial continuity changes with the distance using variograms as tools to reach this goal. Besides, geochemical data assessments of samples collected at drillings C9015A and C9016A are analyzed and discussed here. This paper is a preliminary outcome of a project which purposes to develop a geological 3D model applying geostatistical techniques to an integrated data set, leading an optimizing mineral exploration.

2. Methods

2.1. Electrical resistivity

In general, resistivity of rock is commonly controlled by rock porosity and the salinity of the pore water. In addition, clay and sulfide are electrically polarized and rocks containing them are highly conductive.

JAMSTEC-SIP provided six resistivity loggings, indicating different layers with alike material content.

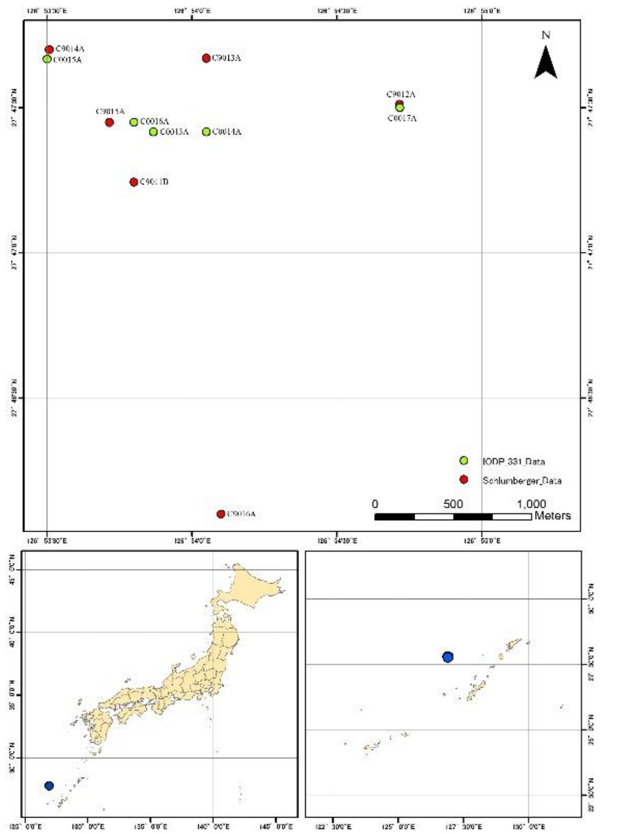

Fig. 1: Distribution of drills performed by JAMSTEC-SIP (red points) and IODP Exp. 311 (green points) in the study area.

2.2. Variography

Variogram is a useful tool to describe the process of determining whether there is spatial correlation among regionalized data measured in the field. This variography includes: testing spatial correlation between the field measurements of the same variable; computing spatial covariance between the data, including calculating semivariance for each pair of observations and; presenting the calculated semivariances graphically as a semivariogram (Kresic, 2006).

In this step, the gauged electrical resistivity beforehand is used as input to generate charts that describe how their spatial continuity changes as the distance is increased by the six omnidirectional variograms. The data were vertically calculated for each drilling site.

2.3. Geochemical analysis

In general, geochemical analysis is aimed at the determination of elemental concentrations in a sample. Likewise, our current data have been analyzed by inductively coupled plasma massive spectrometry (ICP-MS). These data are statistically interpreted, in order to identify anomalies, which may be understood as statistically grouping data and comparing them with geology and sampling information.

Unlikely the current resistivity logging that measurements reach more than the 100 m depth, the geochemical data were limited within the shallow depths at the location C9015A and C9016A, the 25 and 50 m depth ranges below the sea floor (mbsf), respectively.

3. Results and Discussion

Based on the resistivity variograms related to the six drillings (Fig. 2), all of them follow the characteristics of a spherical model, which presents a linear behavior at small separation distances near the origin but flattens out at long distances. In general, the variograms show behavior akin to each other. Aside from the drilling C9015A, they may be described as variograms with small variance. As for C9015A, there is a large variance, reflecting its resistivity logging that shows a discrepancy in its data, in particular between the 15 and 25 mbsf. This study clarified an important trend: the further the drilling is from the chimney the greater the range is, such as for C9011B, C9012A and C9013A, 43.65, 43.11 and 60.82 m, respectively.

The chemical analyses were carried out for a wide range of elements, and the major ones (Zn, Cu, and Pb) were statistically considered anomalous, regarding measures of central tendency such as medians and histograms. The latter and coefficient of variation (CV) can indicate whether a data set is heterogeneous. The histograms does not show the data fall into several groups in any drilling, but measured CV using data from C9016A show values higher than 2, i.e. they are heterogeneous. It may originate from a mixing of data from different facies with homogeneous values in the facies. As for the correlation between the elements, Zn showed strong correlation with Cu and Pb in both drillings.

4. Conclusion

The careful use of variogram can be a remarkable tool to evaluate data set, such as electrical resistivity. Although the wise choice of parameter at experimental variogram, its model must be taken into account. Otherwise, it can reflect an unreal environment. Statistical analysis are important to identify heterogeneity of data, averting a misleading geostatistical approach. More researches are now undergoing to better understanding the study area.

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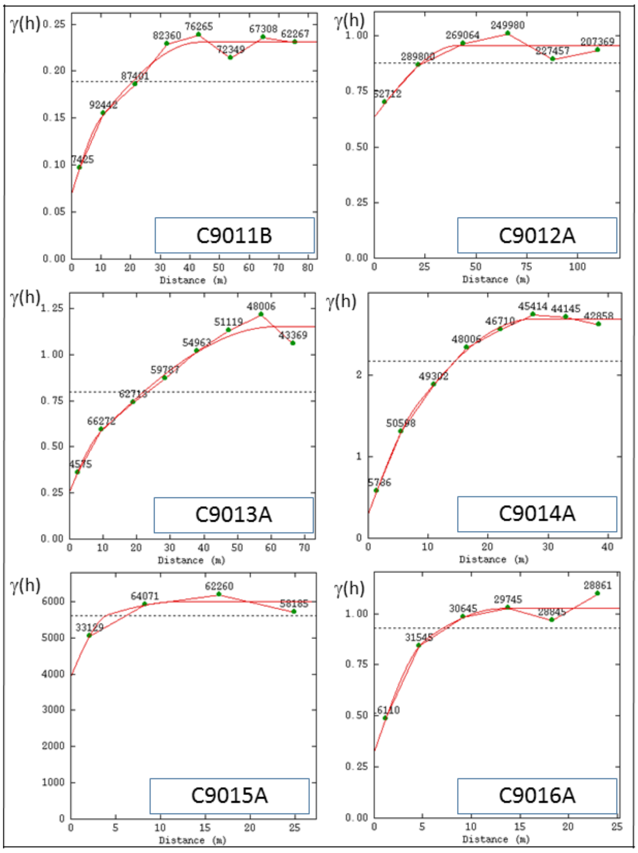

Fig. 2: Electrical resistivity variogram models of each drilling performed by JAMSTEC-SIP in the study area.

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