Manganese concentration of hydrothermal plume at Pele's Pit, Loihi Seamount, Hawaii

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Non – Technical Summary

The Hawaiian Archipelagos have been generated by volcanic activity of the Hawaiian hot spot for 28 million years. Loihi Seamount is known as 'an Island in the womb'. Volcanic activities suggest that this seamount will be the next Hawaiian Island to be created by the hotspot. After a spectacular seismic event in 1996, near the summit of Loihi seamount, a new pit crater was created which is known as Pele's pit. The newly formed Pele's pit was discovered to contain active hydrothermal vent fields. Hydrothermal venting is known to be a major source of Manganese in the ocean. Distinctiveness of hydrothermal vent is that it is emitting hot temperature fluid and various trace metal elements like Manganese. The materials emitted from hydrothermal vent form plumes that seek neutral buoyancy. The hydrothermal plume often shows anomalies of increasing temperature and decreased light transmissivity due to existence of various dissolved trace metals compared to surrounding seawater.

The purpose of this project is to compare and interpret the concentration of dissolved Manganese in hydrothermal plume of Pele's pit to the previously found Manganese concentration in hydrothermal plume at Juan de Fuca Ridge. Comparative data from the Juan de Fuca ridge hydrothermal plume is taken from a study at Cleft Segment done by Massoth et.al. 1994. I hypothesized that Mn concentration of hydrothermal plume at Pele's pit is considerably lower than the Mn concentration of hydrothermal plume at Cleft Segment. Weaker seismic activity and lower vent fluid temperature at Pele's pit compared to Juan de Fuca Ridge supported my hypothesis. The relationship between Manganese concentration and temperature anomaly is quite linear (Coale et al. 1991).

After the field work on R/V Thompson and trace metal analysis at NOAA, result showed mean concentration of Mn of 17.19nmol/L. It was considerably lower than the average Mn

concentration from Cleft Segment as I expected. According to the previous research, mean concentration of dissolved Mn from hydrothermal plume at North Cleft segment during 1986 to 1991 was 93nmol/L. The result of this comparison was significant that it confirmed positive relationship between seismic activity and concentration of Manganese in hydrothermal plume of the site and clearly distinctive characteristics of two vent sites.

Acknowledgement

This research could not have been possible without some awesome people who have been either directly or indirectly involved in the development of my research. I would like to thank Professor Rick Keil and Rika Anderson for giving me precious advices and moral supports. I also would like to thank my classmate Ben Metz for showing patience with many procedures of my project. I want to send appreciation to captain and crew members of R/V Thompson for the safe cruise. Successful collection of samples was possible because of professional help from Mr. Jim Postel and marine technicians. I also want to thank Nathaniel Buck at NOAA PMEL for helping me with laboratory analysis. I really appreciated lots of advices from Danny Grunbaum, Charlie Erikson, and Kathy Newell that helped developing my project. I also want to say thanks to all my classmates in Ocean444 for supporting me in enormous ways. Finally, I send appreciation to my family for watching me finishing UW oceanography senior thesis

. **Abstract**

The object of this project is to compare and interpret the mean concentration of dissolved Manganese in hydrothermal plume of Pele's pit, Loihi Seamount sitting on Hawaiian hotspot to the previously found mean Manganese concentration in hydrothermal plume at North Cleft Segment, Juan de Fuca Mid-ocean Ridge during 1986 to 1991 done by Massoth et al. 1994. My hypothesis was that concentration of Mn from Pele's Pit would be lower than the concentration of Mn Juan de Fuca Ridge. Weaker seismic activity and lower vent fluid temperature at Pele's pit compared to Juan de Fuca Ridge supported my hypothesis. The relationship between Manganese concentration and temperature anomaly is quite linear (Coale et al. 1991). When there was strong seismic activity presented in a site, it showed significantly higher value of Mn concentration from hydrothermal plumes compared to value of Mn concentration measured during seismically inactive period from same site (Malahoff et al. 2006). Manganese last longer than any other element from bacterial consumption proving that manganese is a useful tracer of hydrothermal plumes. Measuring of manganese in a research site would provide well established clues about intensity of seismic activity of the site and characteristic of hydrothermal vent in the site.

During December 24th 2010 to January 4th 2011, research cruise in R/V Thompson was held. Total of 37 samples of hydrothermal plume were collected using CTD cast and conducting four tow-yo transects. After the cruise, samples were analyzed in a laboratory for dissolve Mn concentration. The result showed mean concentration of dissolved Mn of 17.29nmol/L. The standard deviation was 38.24. The mean dissolved Mn concentration from Juan de Fuca ridge given by Massoth et al.1994 was 93±53nmol/L; my hypothesis turned out to be correct. The result of this comparison was significant because it proved that there is a linear relationship

between intensity of seismic activity and Manganese concentration in hydrothermal plume of a region. It also confirmed that distinctive difference in characteristics of the two vent systems such as fluid temperature is correlated with Manganese concentration in the plume that they dispersed.

Introduction

Hydrothermal vents provide a major source of dissolved manganese to the oceans (Manderneck et al. 1993). The Loihi vent is unique; it is the youngest manifestation of the Hawaii hot spot and probably will be the next Hawaiian island (Malahoff et al. 2006). Pele's pit is in the summit of Loihi Seamount (~940m) and was formed by magmatic-tectonic event there in 1996 which led to collapsing of pre-existing Pele's vent in to a larger pit (Malahoff et al. 2006). The newly formed Pele's pit was discovered to contain intensely concentrated hydrothermal plumes (Duennebier et al. 1997).

Manganese is useful marker of the magnitude and evolution of the effects of magmatic perturbation on hydrothermal systems influenced by chronic magmatic degassing (Malahoff et al. 2006). It has been determined that the relative sequence of removal from the plume is$H_2 > \Delta c > {}^{222}Rn > CH_4 \gg Mn$ (Kadko et al.1990) which means that concentration of manganese last longer than any other element proving that manganese is useful tracer of hydrothermal plumes. Measuring of manganese in a research site would provide well established clues about intensity of seismic activity of the site and characteristic of hydrothermal vent in the site.

The purpose of this project is to examine the concentration of dissolved Manganese in hydrothermal plume at Pele's pit and compare the value with previously studied concentration of dissolved Manganese in hydrothermal plume at different hydrothermal vent fields. I chose data from Massoth et.al.1994 which studied hydrothermal plume at North Cleft Segment, Juan de Fuca Ridge during 1986 to 1991 as comparative data.

There were two main reasons why I chose Juan de Fuca Ridge as a comparing site. One is difference of seismic activity levels between Hawaii Islands and the Juan de Fuca Ridge. Region of Juan de Fuca plate had been known for strong volcanic activity during 1986 to 1991 explained by volcanic erupted sedimentation and occurrences of megaplumes (Embley et. al.1991). From the daily updated earthquake data provided by USGS (http://earthquake.usgs.gov/earthquakes/recenteqsww/Maps/region/N_America.php), it was noticeable that there had not been earthquake stronger than magnitude of 3 during November 2010 to January 2011. According to Malahoff et al. 2006, when there was strong seismic activity presented in a site, it showed significantly higher value of Mn concentration from hydrothermal plumes compared to value of Mn concentration measured during seismically inactive period from same site. Differences of fluid temperature at two vent fields were noticeable as well. According to Bemis et. al. 2002, there were numbers of black smokers activating at Cleft Segment that were emitting vent fluid with hot temperature that was in range between 295◦C and 328 ◦C. Malahoff et. al. 2006 mentioned that since the major seismic activity that occurred in 1996, maximum temperature of hydrothermal vent fluid of Loihi has been progressively decreasing from 198◦C to 93◦C while the concentration of Mn has been progressively decreasing as well. My understanding is that concentration of Manganese in hydrothermal plumes is in a linear relationship against level of seismic activity and temperature of vent fluid.

My hypothesis for this project is that manganese concentration of plume of hydrothermal vent of Pele's pit would be considerably lower than value of manganese concentration of plume of Juan de Fuca Ridge hydrothermal vent studied previously during 1986 to 1991 because Pele's pit showed measurably lower fluid temperature and weaker seismic activity compared to Juan de Fuca Ridge. If this is so, it implies that there are positive relationships between Manganese concentrations of hydrothermal plume versus intensity of seismic activity of sites and temperature of vent fluid.

Method

Field Method- All field work was held on cruise in R/V Thompson during December 27th 2010 and January 4th 2011. Figures 1 show the exact location of Pele's pit of Loihi Seamount which its coordinates are 18° 55′ 12″ N, 155° 16′ 12″ W. The length of Pele's pit crater is about 0.5km and range of depth was 1115m to 1218m (Figure 2). Collection of water samples were done by a conductivity/temperature/depth (CTD) system interfaced with a transmissometer. To detect and sample neutrally buoyant plumes, tow-yo was conducted with the CTD system continual raisings and lowerings of the instrumentation through the plume and 5m to 10m away from the bottom while slowly moving at about 1 knot. Total of four transects were done passing by inside wall of each four side of Pele's Pit (Figure 3). Spiking temperature and decreasing transmissivity in water columns were indicators of hydrothermal plumes. Two Niskin bottles were fired when there was a signature of hydrothermal plumes to avoid misfire. At the end, total of 37 samples were collected into trace metal bottles.

Laboratory Method- All 37 samples were acidified to pH less than 2 using ultrapure HCI prior to laboratory analysis. Dissolved Manganese in plume samples was analyzed in the NOAA laboratory. The concentration of Mn was determined using flow injection analysis (Tecator FIAStar 5010) and colorimetric detection following kinetic oxidation of N, N-Diethlaniline by potassium periodate, catalyzed by Mn. For low concentration of Mn, on-line preconcentration using DETATA (diethylentriaminetetraacetic acid) was employed (Malahoff et. al.2006). The detection limit for Mn was 0.04 nmol/L

Result

Concentration of dissolved Mn determined from 37 samples was in range between 0.75nmol/L and 235.66nmol/L (Table 1). Mean of dissolved Mn concentration is 17.29nmol/L; comparing value of mean dissolved Mn from North Cleft Segment was 93nmol/L (Massoth et al. 1994) (Table 2). The Standard deviation of all the data was 38.24. Temperature range of collected neutrally buoyant plumes ranged from 3.12◦C to 4.13◦C. Plume temperature and the result of Manganese concentration did not show any relationship (Figure 4). Out of four transects third transaction which went by southern inner wall of Pele's Pit showed the highest mean concentration of 23.71nmol/L. Second transect which went by eastern inner wall of the pit showed the lowest mean concentration of 6.25nmol /L.

Discussion

My hypothesis claimed that there would be considerably less value of concentration of Mn in hydrothermal plume at Pele's Pit compared to value of Mn concentration from Massoth et al. 1994 in plume at North Cleft Segment during 1986 to 1991. My hypothesis turned out to be correct as mean concentration of 17.29nmol/L was shown from 37 samples collected from Pele's Pit which is much smaller than mean concentration of 93nmol/L. To support my hypothesis, I suggested lower temperature of vent fluid and weaker seismic activity of Pele's Pit compared to North Cleft Segment, Juan de Fuca Ridge.

Even though the mean concentration of Mn in hydrothermal plume from two sites correlated with my hypothesis, each individual Mn concentration data collected from the Pele's Pit did not show a linear relationship against plume temperature (figure 4). One possible explanation for this trend is that depth range of this research which was between 5m to 10m from the bottom of the pit was too small to show such a relationship. Perhaps if the data collection was done through much larger depth range for example 0.1m to 50m from the bottom of the Pele's pit, we might be able to observe clearer trend of linear relationship between Mn concentrations and plume temperature.

There was a one sample that showed unreasonably large value of Mn concentration. Sample number 28 from third transect showed Mn concentration of 235.66nmol/L. Considering the fact that the mean value of 37 samples was 17.29nmol/L and the second largest value was only 47.62nmol/L, the sample might had a error during trace metal analysis procedure. Figure 5 shows a plot of plume temperature against the Mn concentration ignoring the sample number 28. It still does not show a linear relationship between Mn concentration and the plume temperature. It was meaningful because it informed again that bigger depth range of research is necessary to find such a relationship.

If I exclude the sample number 28 from the data set, out of the four transects, the first transect shows dominantly the largest both mean Mn concentration value and the plume temperature (Table 4). The first transect is the transect that is closest to the summit of Loihi Seamount (Figure 3). It could be possible to say that along the first transect was conducted, there are relatively active hydrothermal vent systems compared to the other parts of Pele's pit.

If Hawaiian hotspot was vigorously active which often was in geological time scale, the result would be different. According to Malahoff et al. 2002, when they did rapid response cruise after a spectacular seismic event in 1996 at Loihi Seamount, they found mean concentration of dissolved Mn of 3700nmol/L in hydrothermal plumes which is nearly magnitude of 2 greater than 17.29nmol/L which is mean Mn concentration found in this project. Monitoring and discovering concentration of trace metal such as Manganese in hydrothermal plume from various vent fields would give us meaningful clues about geological condition of research sites and characteristics of hydrothermal vent system that dispersed the plume. Prior to finishing laboratory analysis and getting the results, my expectation of mean concentration of Mn was 16nmol/L and was suggested only based on data gathered in seismically inactive year from Malahoff et al. 2002 because I believed that Loihi Seamount was having weak seismic activity during the time of the research cruise. I personally was surprised that it was very close to the mean Mn concentration collected from this project which was 17.29nmol/L. It might indicate that consistency of trace metal concentration in hydrothermal plume is solely depending upon the level of seismic activity in the region

Conclusions

- Concentration of dissolve Mn in hydrothermal plume of Pele's Pit is considerably lower than Mn concentration in hydrothermal plume of North Cleft Segment during 1986 and 1991.
- Hypothesis of this project turned out to be correct
- Concentrations of Manganese have been showing positive relationship against temperature of vent fluid and level of volcanic activity.

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Figures

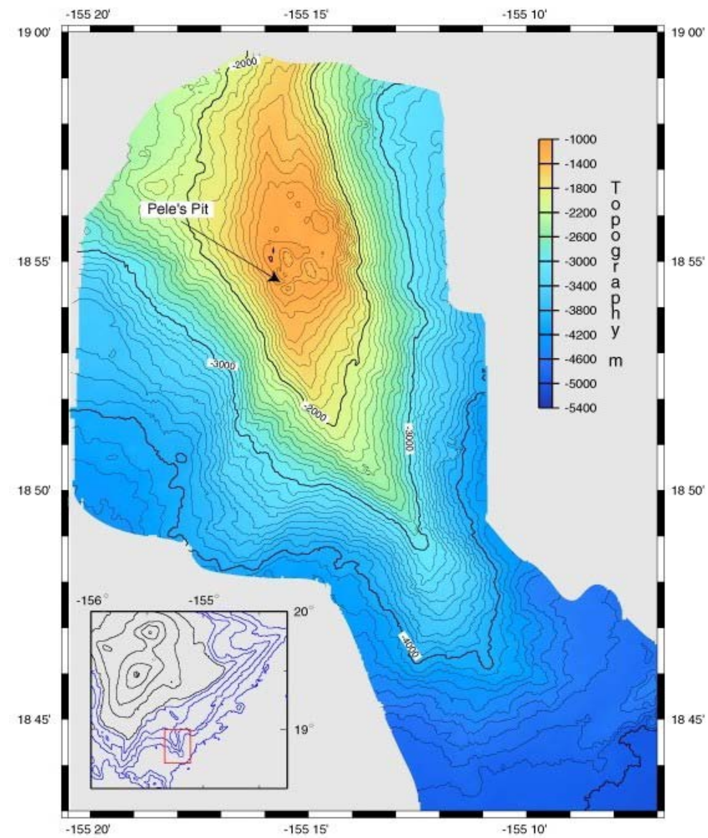

Fig 1-

Fig.1

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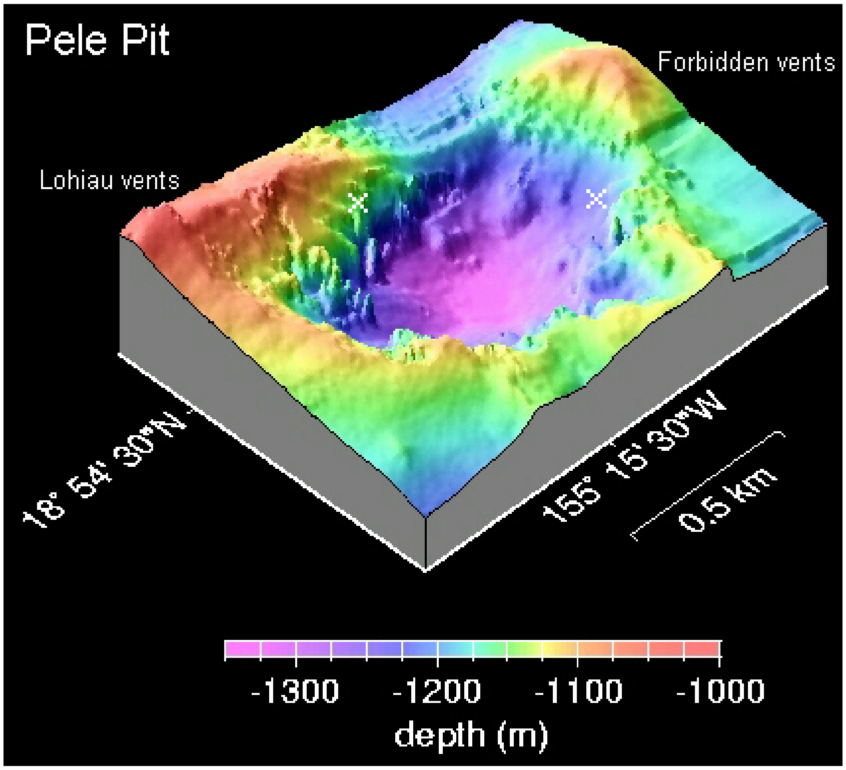
Pele Pit
Forbidden vents
Lohiau vents
18° 54' 30"N
155° 15' 30"W
0.5 km
-1300
-1200
-1100
-1000
depth (m)

Fig. 2

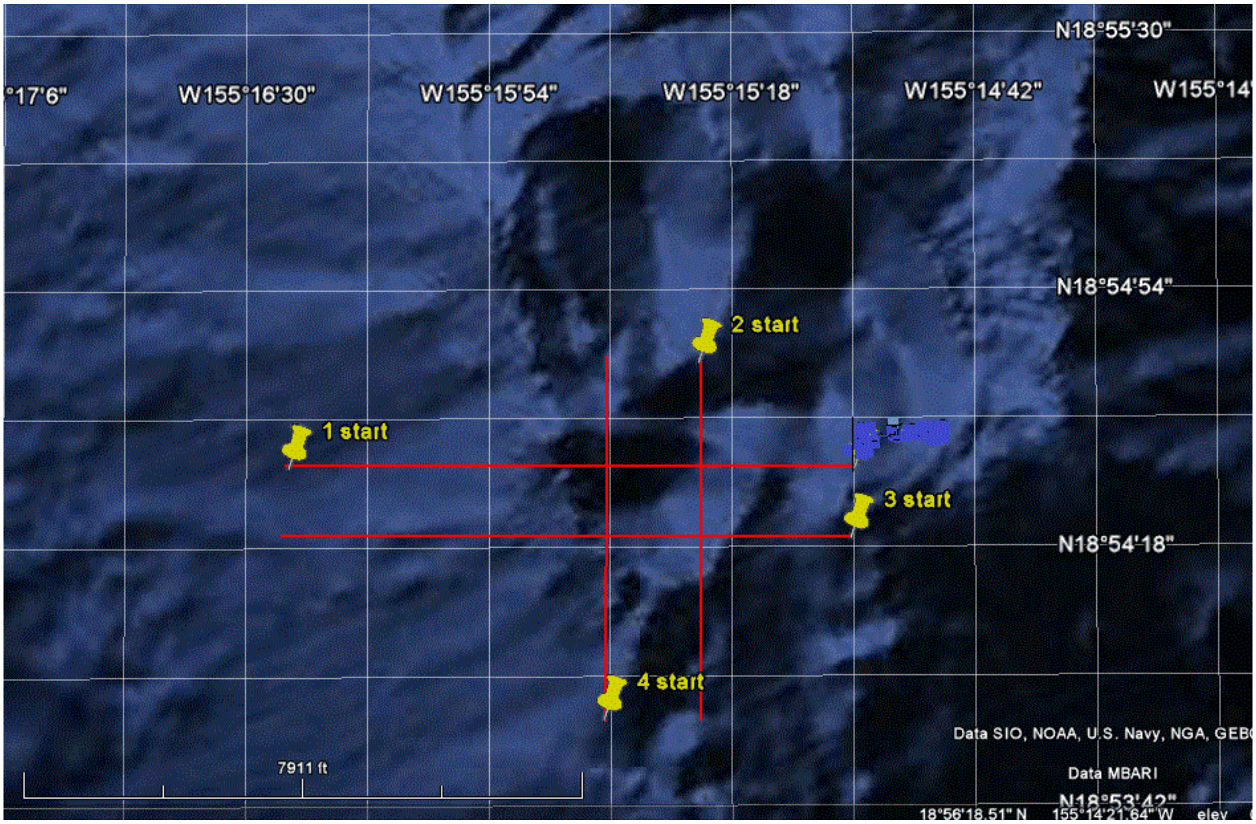
N18°55'30"
°17'6"
W155°16'30"
W155°15'54"
W155°15'18"
W155°14'42"
N18°54'54"
2 start
1 start
3 start
N18°54'18"
4 start
Data SIO, NOAA, U.S. Navy, NGA, GEB
7911 ft
Data MBARI
N18°53'42"

Fig.3

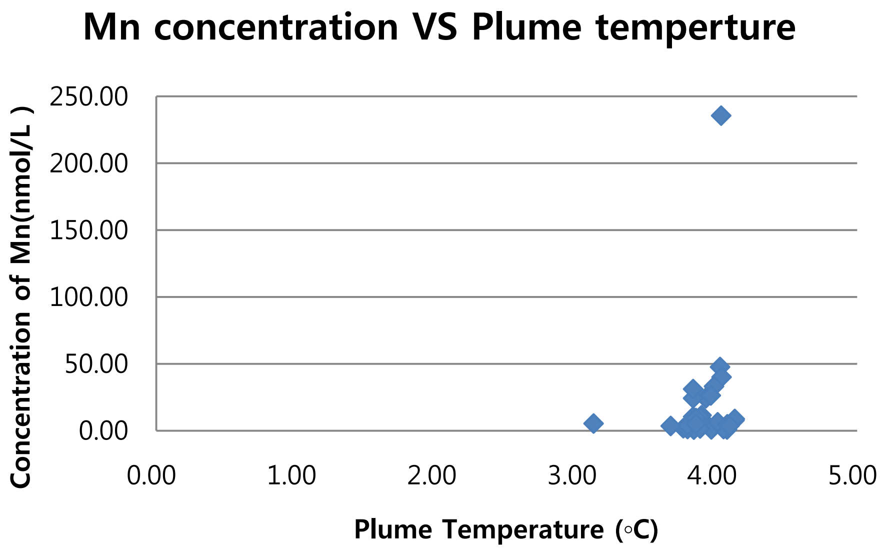
Mn concentration VS Plume temperture
Concentration of Mn(nmol/L)
250.00
200.00
150.00
100.00
50.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
Plume Temperature (◦C)

Fig. 4

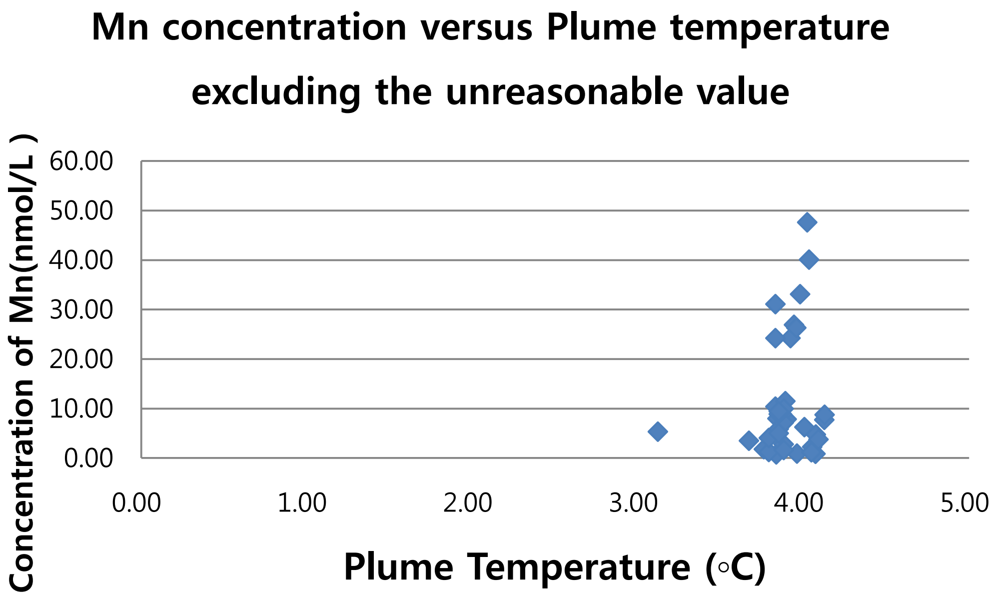
Mn concentration versus Plume temperature
excluding the unreasonable value
Concentration of Mn(nmol/L)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
Plume Temperature (◦C)

Fig. 5

Figure Legends

Fig.1. Location of Pele's pit in Loihi Seamount

(http://www.research.noaa.gov/spotlite/archive/spot_loihi.html)

Fig.2. 3D bathymetric map of Pele's pit; its depth and length are shown.

(http://www.soest.hawaii.edu/GG/HCV/loihi-newpit.html)

Fig.3. Four transactions going by each inner wall of Pele' Pit

Fig.4. Profile of Mn concentration versus Plume temperature

Fig.5. Profile of Mn concentration versus Plume temperature excluding the unreasonable value.

Tables

Table1- Table of all the sample information

Depth (m)	Temperature (◦C)	Concentration of Mn(nmol/L)	Transect#	sample#
1058	4.13	7.73	1	1
1059	4.13	8.75	1	2
1088	4.05	2.26	1	3
1089	4.07	0.87	1	4
1084	4.02	47.62	1	5
1082	4.03	40.09	1	6
1091	3.94	26.92	1	7
1093	3.92	24.24	1	8
1113	3.98	33.11	1	9
1114	3.96	26.32	1	10
1132	3.90	7.86	1	11
1176	3.84	0.75	2	12
1182	3.84	7.99	2	13
1183	3.88	2.79	2	14
1162	3.87	8.85	2	15
1124	3.83	10.40	2	16
1135	3.85	5.88	2	17
1126	3.89	11.50	2	18
1118	3.96	0.91	2	19
1136	3.88	7.14	2	20
1195	3.76	1.80	3	21
1192	3.79	1.23	3	22
1210	3.79	4.07	3	23
1204	3.12	5.34	3	24
1174	3.85	8.89	3	25
1136	3.88	9.97	3	26
1138	3.88	1.63	3	27
1140	4.03	235.66	3	28
1129	4.05	1.18	3	29

1128	4.01	6.26	3	30
1126	4.07	4.76	3	31
1117	4.09	3.77	3	32
1171	3.67	3.51	4	33
1115	3.85	9.44	4	34
1127	3.85	5.02	4	35
1164	3.83	24.23	4	36
1129	3.83	31.10	4	37

Table 2- Comparison of mean concentration of dissolved Mn of Pele's pit hydrothermal plume and North Cleft Segment hydrothermal plume from Massoth et al. 2002

Mean concentration of dissolved Manganese in hydrothermal plume at Pele's Pit. (nmol/L)	Mean concentration of dissolved Manganese in hydrothermal plume at North Cleft Segment during 1986 to 1991 from Massoth et al.2002. (nmol/L)
17.29	93 ± 56

Table 3- Detailed coordinates for start and end of each transect. Track lines are shown in fig. 4

Transect #	Start coordinate	End coordinate
1	18°54.47'N, 155°16.40'W	18°54.47'N, 155°14.00'W
2	18°54.73'N, 155°15.38'W	18°53.90'N, 155°15.38'W
3	18°54.32'N, 155°14.00'W	18°54.32'N, 155°16.40'W
4	18°53.90'N, 155°15.62'W	18°54.73'N, 155°15.62'W

Table 4.

Transect#	Concentration of Mn(nmol/L)	Temperature (◦C)
1	20.52	4.01
2	6.25	3.87
3	4.44	3.86
4	14.66	3.806