南沖繩海槽新發現熱液活動區之地化特徵 Geochemical Characteristics of New Discovered Hydrothermal Activity Zone in South Okinawa Trough

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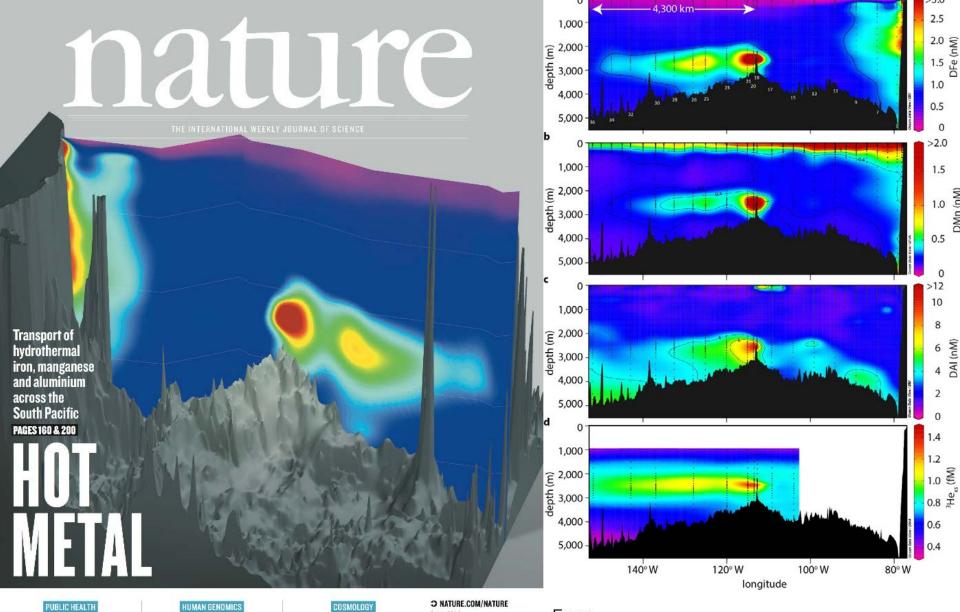
4國立中山大學海洋科學系

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國立臺灣大學海洋研究



ENDGAME FOR HIV

We have the tools to quash the epidemic PAGE 146

REACH FOR THE CLOUD

Embrace a data commons to speed processing PAGE 149

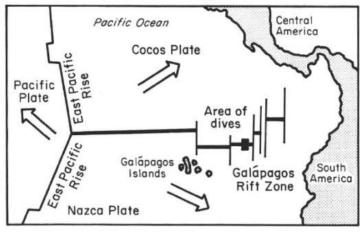
CATCH A FORMING STAR How feedback slowed star

How feedback slowed star formation in early Universe PAGE 189



From http://www.washington.edu/news/2015/07/08/seafloo r-hot-springs-a-significant-source-of-iron-in-the-oceans/

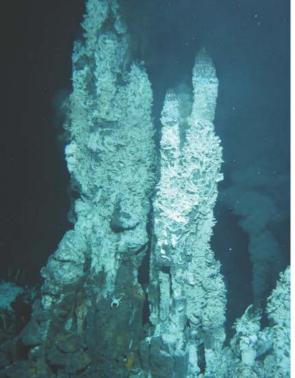
Since 1977... Discovery of Hydrothermal systems



Ballard (2002, WHOI)



From http://www.bluebirdelectric.net/submarines/alvin_dsv_submersible_woo ds hole oceongraphic institution us navy.htm







From http://www.the-scientist.com/?articles.view/articleNo/32524/title/Bottom-Dwellers/

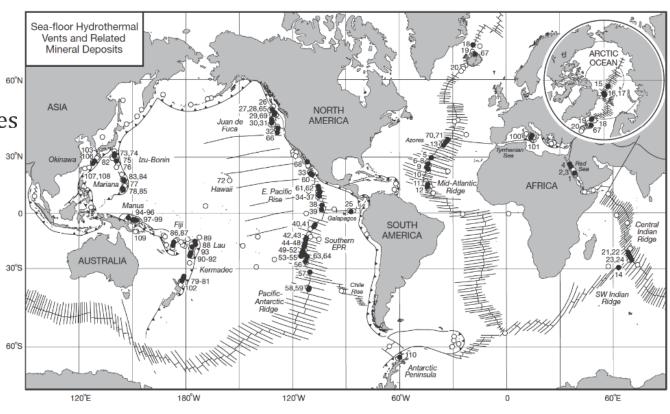
Distribution of Hydrothermal Systems

◆ Mid-ocean ridges

◆ Sediment-covered ridges and related rift

◆ Island arcs and related back-arc rifts

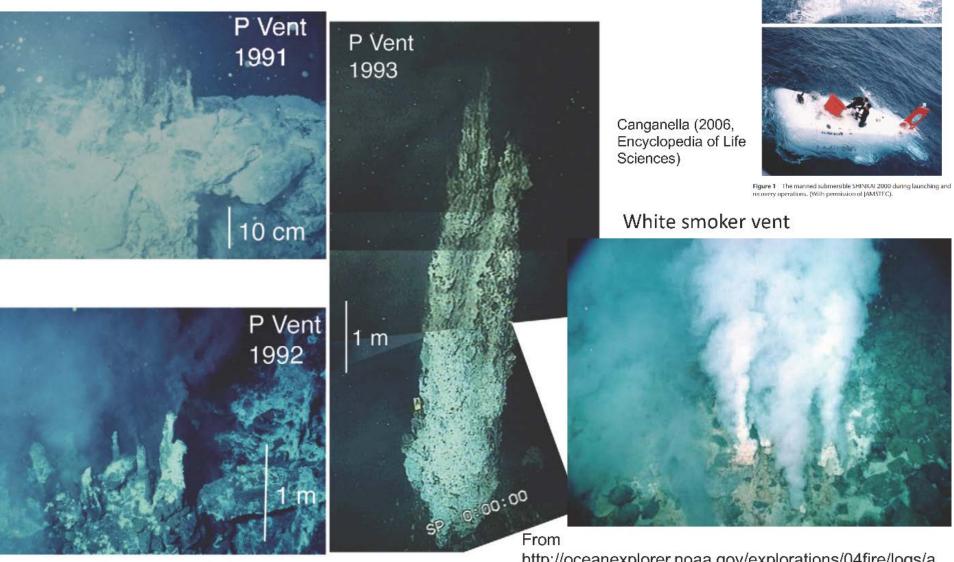
♦ Back-arc basin



Hannington et al. (2005)

Observations of Hydrothermal vent systems

East Pacific Rise at 9°-10°N



Haymon (2001, Encyclopedia of Ocean Sciences)

http://oceanexplorer.noaa.gov/explorations/04fire/logs/april12/media/champagne_vent.html

Hydrothermal vent ecosystems



Figure 2 An impression of hydrothermal vent area and representative associated organisms. (Modified after *FOCUS* magazine, geographic design: Mario Russo).

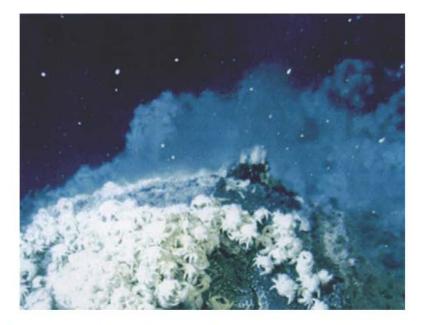


Figure 3 A black smoker located at 1300 m depth along the Okinawa Trough. (With permission of JAMSTEC).

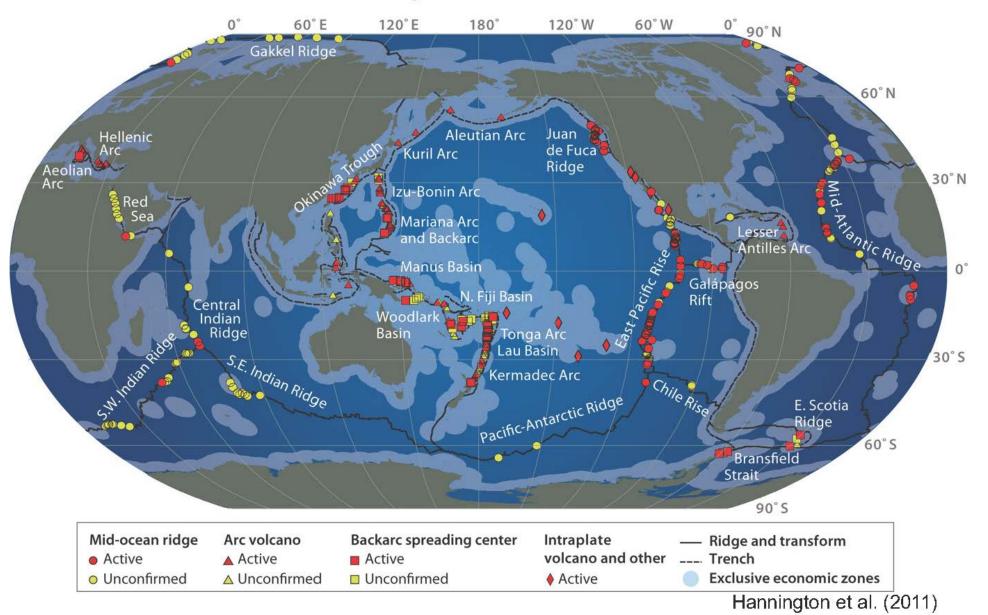


Figure 5 The tubeworm *R. pachyptila* typically found at the East Pacific Rise and the Guaymas Basin.

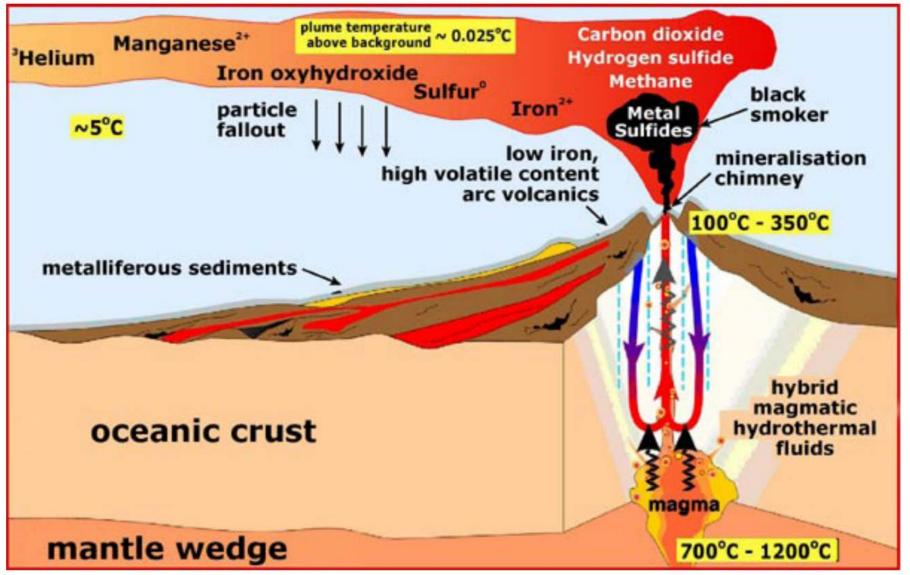
Canganella (2006, Encyclopedia of Life Sciences)

1. Submarine Hydrothermal Minerals Exploration

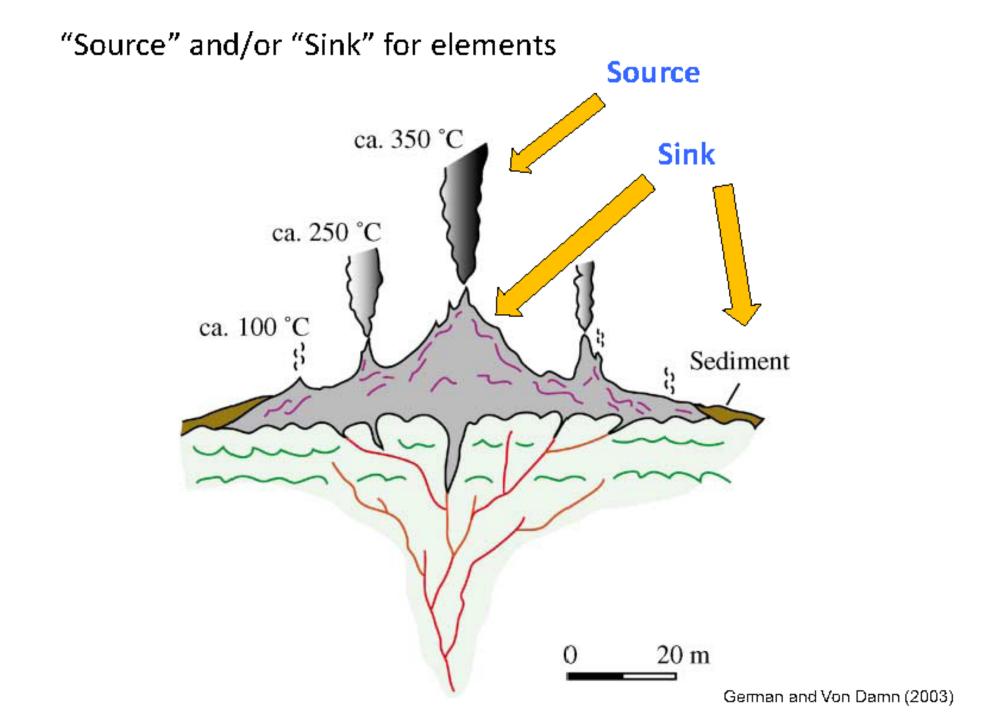
Seafloor Massive Sulfide deposit



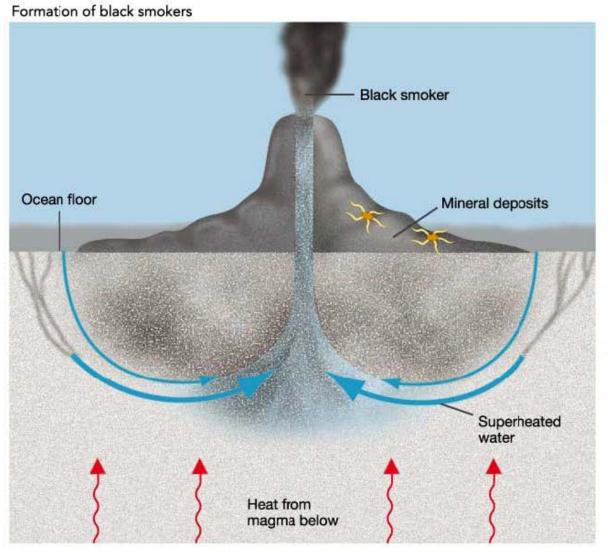
2. Effect of hydrothermal inputs for chemical balance in ocean



From http://oceanexplorer.noaa.gov/explorations/06fire/background/chemistry/media/arcvolcano.html



Factors controlling chemical compositions of vent fluids



- Chemistry of initial fluids
- Circulation path
- ◆ Temperature of system
- ◆ Water-rock interaction
- Phase separation
- ◆ Magmatic influence

Hydrothermal circulation

Mg-consumption during w/r interaction

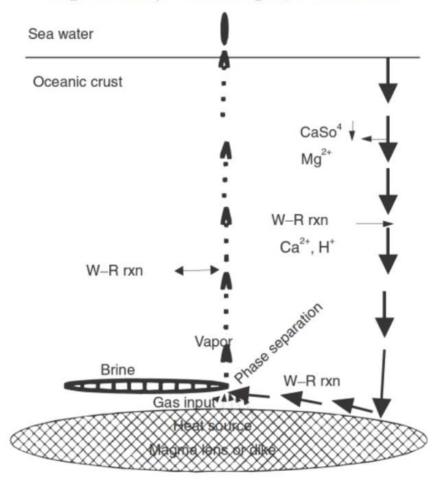
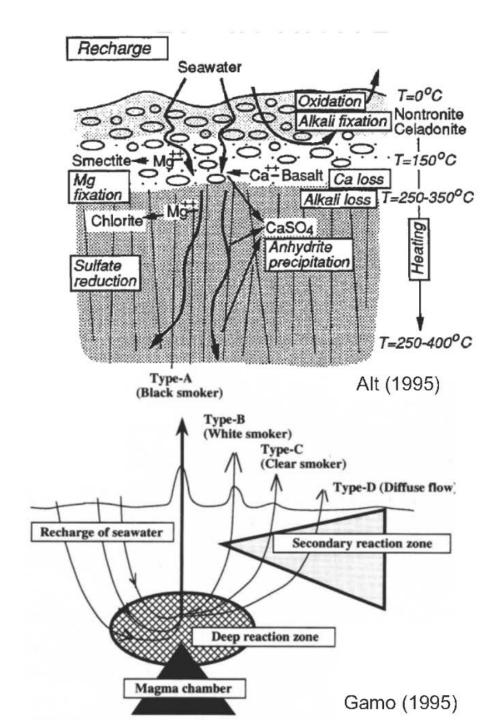


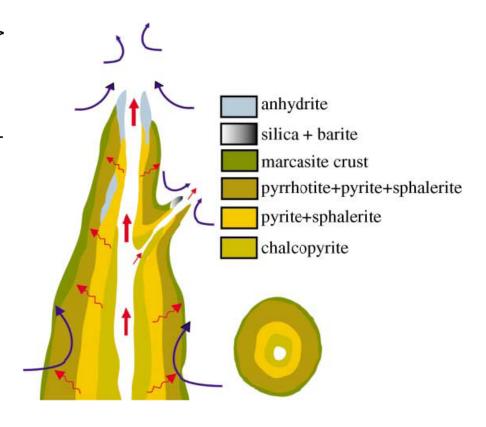
Figure 3 Schematic of a hydrothermal flow cell. W-R_{rxn} = water-rock reaction. (Von Damm 1995 in Humphris *et al.*)

Von Damm (2001)



Effect of phase separation

- ◆ The relative order of partitioning into the brine was Ba > Sr > Ca > K > Na, Cl > Li > Br > B. [Berndt and Seyfried, 1990, GCA]
- ◆ High concentrations of Mn and Zn in high-Cl fluids, but high Fe and Cu contents in low-Cl fluids. [James et al., 2014, GCA]
- ◆ Zn, Cd, Pb and Mn are enriched in the brine, whereas Fe, Cu, Ni, Al and Cr are partitioned into the vapor phase. [Valsami-Jones et al., 2005, JVGR]



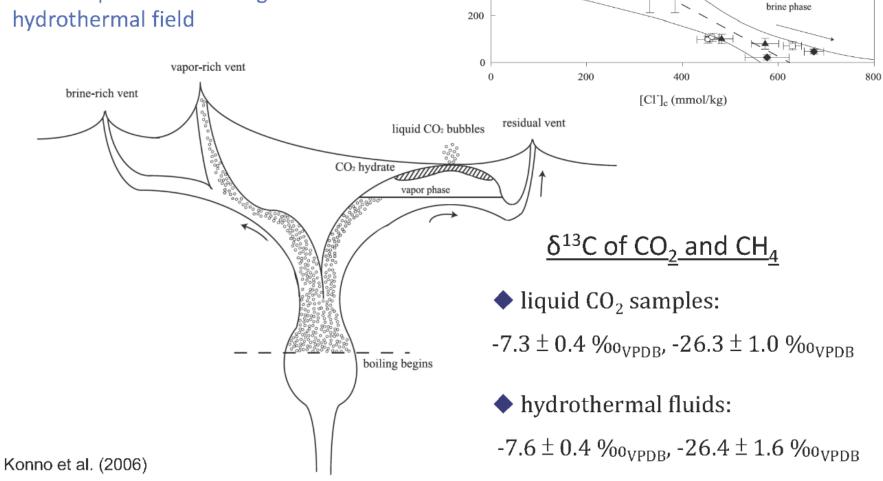
Chemical composition of hydrothermal vent fluid in Okinawa Trough

	Manus Basin		Izu-Bonin Arc	Mariana Trough		North Fiji Basin			Okinawa Trough			Mid-ocean ridge			Seawater
	Vienna Woods	PAC-MANUS	Suiyo Smt.	Alice Springs	Forecast Vent	White Lady	Kaiyo	LHOS	JADE	Minami-Ensei	CLAM	EPR 21°N	Guaymas Basin	Escanaba Trough	
References	1, 2	2	1	1,4	1	1	3		1,6	1	1, 6	1, 4, 5	1, 5	1, 4	1
Mg (mM)	0	0	0	0	0	0	0	0	0	0	~20	0	0	0	52.7
Li (mM)	0.7		0.6	0.59 to 0.83	0.3	0.20 to 0.28	0.28		2.5	5.4 to 5.8	3 to 4	0.89 to 1.48	0.63 to 1.08	1.29	0.03
K (mM)	23	89	30	31 to 48	26	10.5 to 14.5	14.5		72	49 to 51	50 to 60	23 to 26	33 to 49	40.4	9.8
Na (mM)	512	487	446	438	438	210 to 239	239		425	410 to 431		432 to 510	475 to 513	560	464
Ca (mM)	73	18	89	22	61	6.5 to 9.0	9		22	21 to 22	~20	12 to 21	27 to 42	33.4	10.2
Sr (µM)	312	102	303	72 to 90	165	30 to 43	43		94	215 to 227		65 to 97	158 to 253	209	87
⁸⁷ Sr/ ⁸⁶ Sr				0.7036	0.7038	0.7046			0.7089	0.7100		0.7030 to 0.7036	0.7052 to 0.7059	0.7099	0.7092
Cl (mM)	640	639	658	544 to 557	593	255 to 267	267		550	501 to 527	550	489 to 592	580 to 637	668 to 680	540
Rb (μM)				30		8.8 to 17	17.1		360		180 to 220	23 to 28	60 to 86	110	1.3
Cs (µM)				0.8									0.2 to 0.3	5.8 to 6.5	7.7
Mn (μM)	297	3221	587	295	300	12 to 26	26		110	88 to 94	400 to 500	700 to 1020	110 to 236	10 to 21	< 0.001
Fe (µM)	77	4337	435	6.4	11	9 to 13	8.8		2.8			650 to 2430	8 to 180	0 to 10	<0.001
NH_4^+ (mM)		< 0.1	<0.1	0	<0.1	_		\rightarrow	5.0	4.6 to 4.7	8 to 12	<0.01	11 to 16	5.6	0
CO_2 (mM)			34 to 42	43.4	42.1	11.1 to 14.4	11.1		209	64 to 96	160 to 200	5.7 to 8.0	16 to 24	>9	2.3
H_2S (mM)			1.2 to 1.6	2.5	0.4	2.0 to 4.0	4		12.4	1.6 to 2.4	15 to 25	6.6 to 8.4	3.8 to 6.0	1.1	0
Alkalinity (mM)	-0.1	-4	-0.2	0.1 to 0.4	0.18	-0.87 to $+0.12$	-0.87	<u> </u>	1.9	3.0 to 3.5	10 to 20	-0.2 to -0.5	2.8 to 10.6	3.1	2.3
B (mM)	0.54	1.93	1.4	0.75 to 0.81		0.46 to 0.47	0.48		3.4	3.7 to 4.0	5 to 6	0.50 to 0.55	1.6 to 1.7	1.7 to 2.2	0.41
δ ^{1 1} B (‰)				22.5 to 29.8					- 1.0 to 2.2		7.0 to 9.2	29.0 to 32.6	16.5 to 23.2	10.1 to 11.5	39.6
This study	0.52	1 47	1.50	0.73	0.04	0.44	0.55	0.47	4.0	4.4	2.0				
B (mM) δ ¹¹ B (‰)	0.53 29.7	1.47 13.5	1.52 18.5	20.2	0.64 23.2	0.44 36.1	0.55 34.5	0.47 35.3	4.8 2.6	4.4 2.5	3.9 2.9				
Cs (µM)	0.3	2.6	1.8	0.7	0.5	0.1	0.2	0.2	2.6	2.5	2.9 14				
Cs (µw))	0.5	1.8	1.8	0.7	0.5	0.1	0.2	0.2	5.1	6.1	3.7				

Yamaoka et al. (2015)

CO₂ enrichment in Okinawa **Trough hydrothermal system**

Phase separation in Yonaguni Knoll IV hydrothermal field



1000

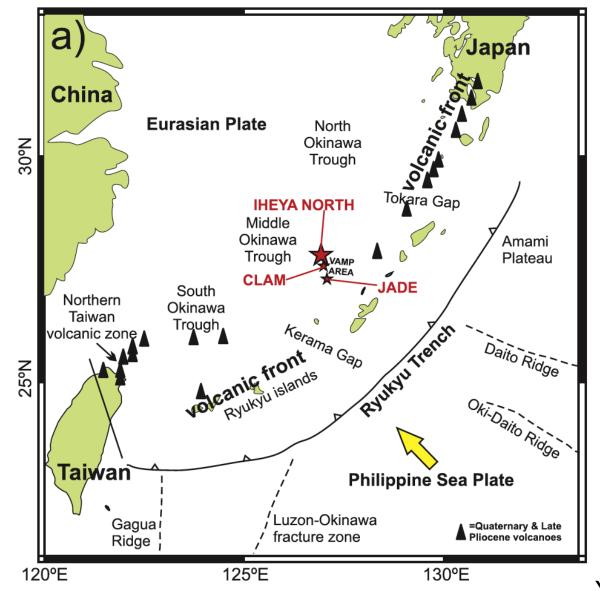
800

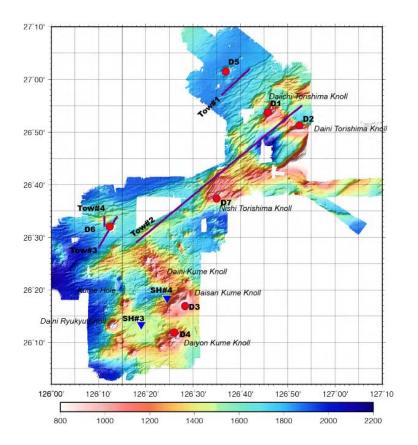
[CO2]c (mmol/kg)

vapor phase

Okinawa Trough hydrothermal system

North. Middle and South Okinawa Trough hydrothermal field

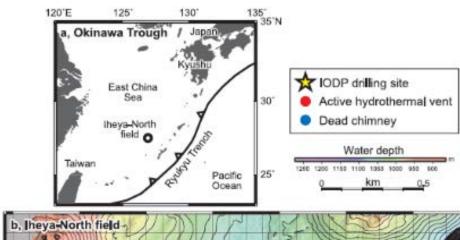


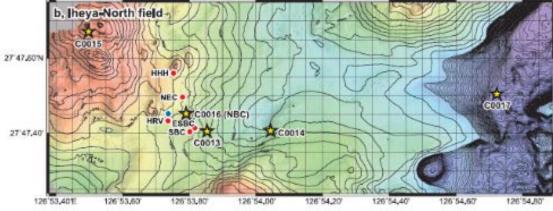


KS-17-14 R/V Shinsei-maru



Yeats et al. (2017)



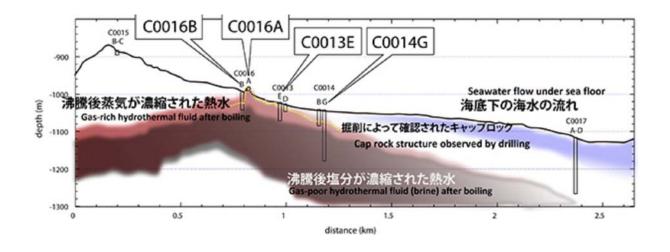




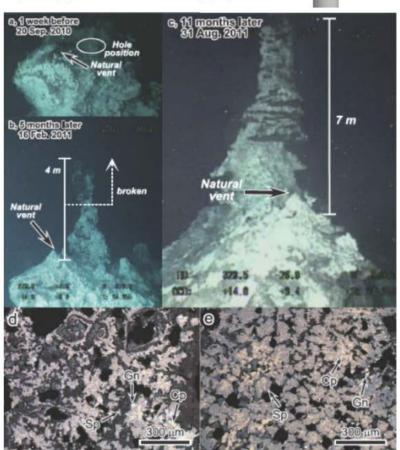
OPEN Rapid growth of mineral deposits at artificial seafloor hydrothermal vents

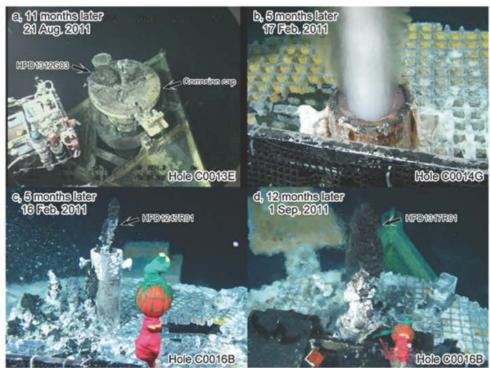
Received: 27 January 2015 Accepted: 08 February 2016 Published: 25 February 2016

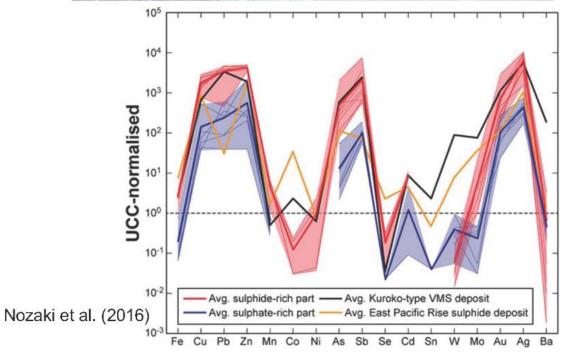
Tatsuo Nozaki^{1,2}, Jun-Ichiro Ishibashi³, Kazuhiko Shimada³, Toshiro Nagase⁴, Yutaro Takaya^{1,5}, Yasuhiro Kato^{1,2,6}, Shinsuke Kawagucci^{1,7,8}, Tomoo Watsuji⁷, Takazo Shibuya^{1,8}, Ryoichi Yamada⁹, Tomokazu Saruhashi¹⁰, Masanori Kyo¹⁰ & Ken Takai^{1,7,8}





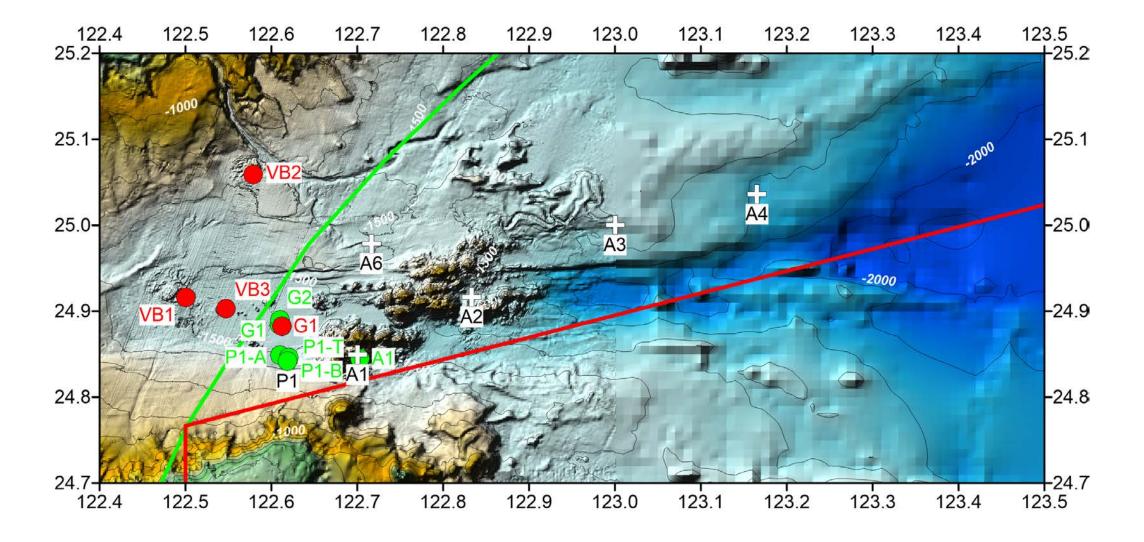


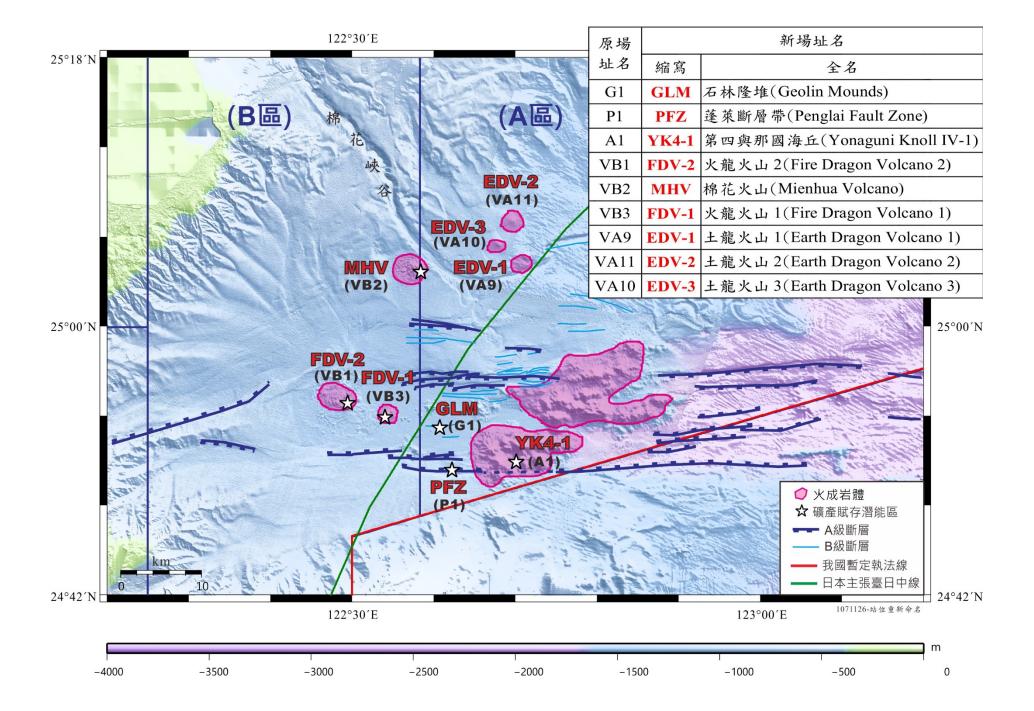




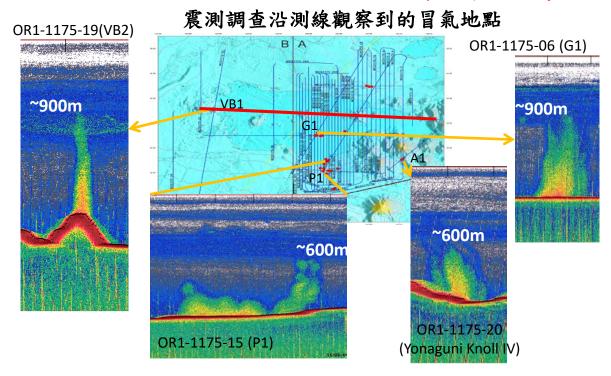
Jade Site及Yonaguni Knoll IV熱液活動與礦化作用特性:

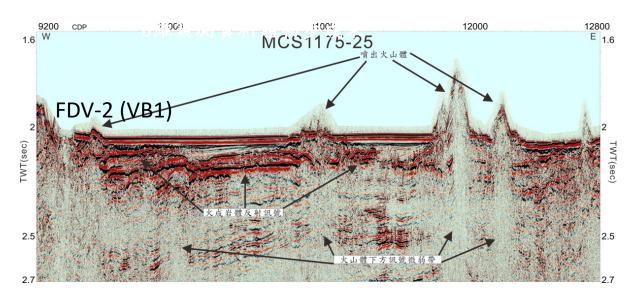
- 噴發與侵入的火成岩體以中性至酸性的安山岩或流紋岩為主,因此其硫化礦和洋脊熱液區(玄武岩為主)同類型熱液沈澱相比,更富含具高經濟價值的金、銀、鋅、銻、砷、鉛等金屬(Glasby and Notsu, 2003)。
- 由於海洋沈積物隱沒,使沖繩海槽的熱液比洋脊熱液更富含二氧化碳。當此一富含二氧化碳的熱液移棲至水深僅1300-1400公尺的海床表層時,可能產生沸騰作用與相分離,造成「富含二氧化碳一氯缺乏」以及「富含氯一二氧化碳缺乏」兩種類型的熱液,除了造就不同類型的礦化作用,也在海床上造成二氧化碳水合物與液態二氧化碳等特殊現象(Konno et al., 2006)。富含二氧化碳的酸性流體在沈積層中移棲時,會對礦物進行滲洗、風化,造成沈積物中的總鹼度值較一般海洋沈積物異常偏高(de Beer et al., 2013),也可能洗脫出沈積物中的金屬離子;而當富含二氧化碳的熱液逸出海床表面,與低溫的海水混合時,常會沈澱出富含稀土元素的碳酸鹽類礦物(Suzuki et al., 2008)。
- 巨厚的沈積物(南沖繩海槽約兩公里厚)對熱液成份與礦化作用有重要影響。除了移棲的熱液對沈積物進行換質、滲洗是造成海床表面硫化礦富含鉛、砷等金屬的原因以外(Glasby and Notsu, 2003),一般咸認在沈積層內也有礦化作用在進行(Expedition 331 Scientists, 2010)。
- 值得注意的是,這些在海床上的礦化作用,具有高度局部性以及礦物學與產狀的多樣性(Suzuki et al., 2008)。



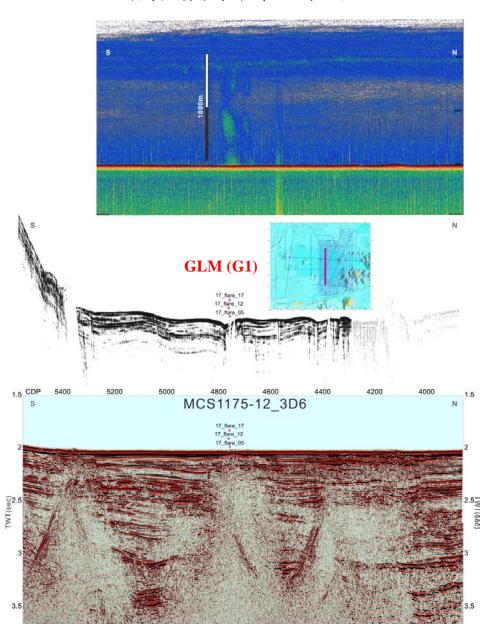


震測及地熱流調查研究團隊





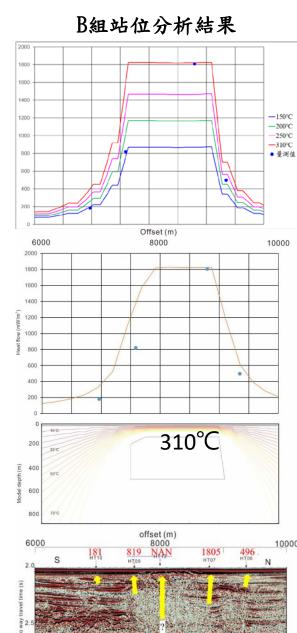
反射震測與海床聲納剖面整合

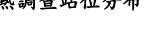


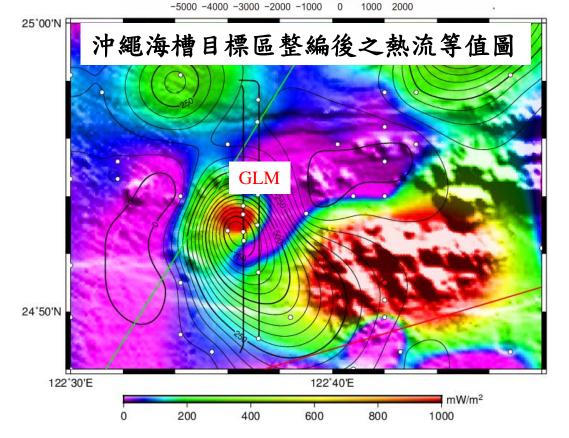
122°30'E 122°36'E 122°42'E 122°48'E 25°00'N 25°00'N ACS1146-8 A組-6站 MCS1175-18-3D9 HT1 24°54'N 24°54'N B組-5站 地熱調查站位分布 Yonaguni Knoll IV 24°48'N 122°30'E 122°36'E 122°42'E 122°48'E

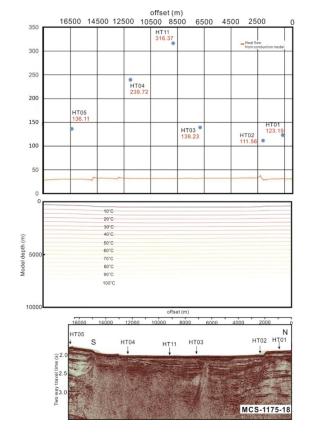
地熱流調查研究

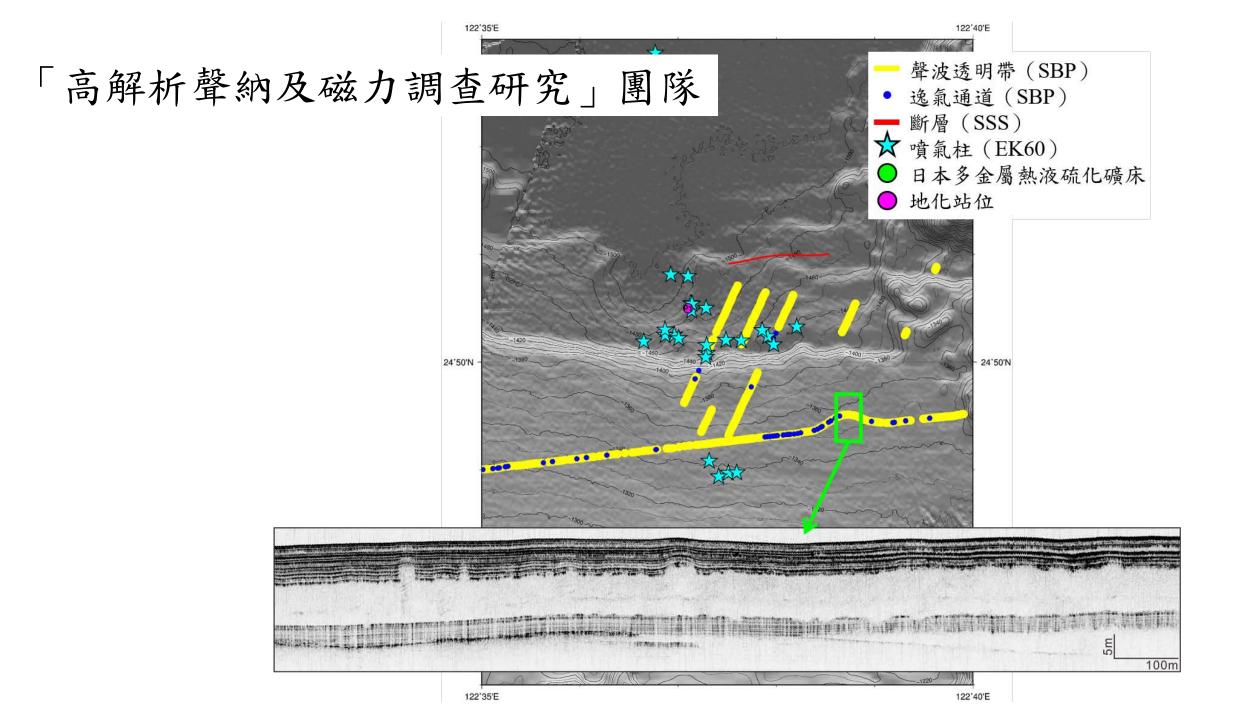
A組站位分析結果



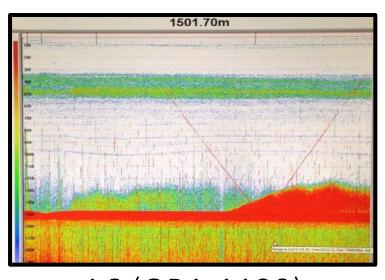




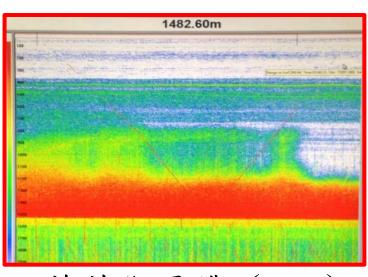




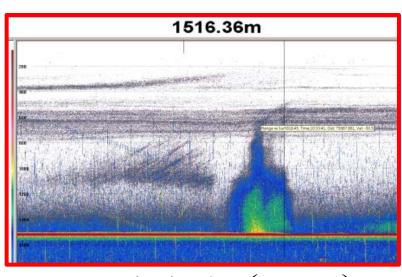
海床流體活動



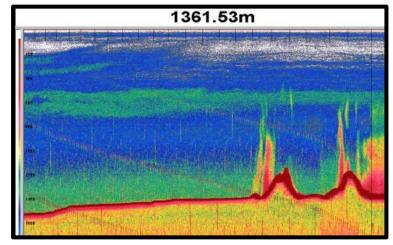
A6 (OR1-1139)



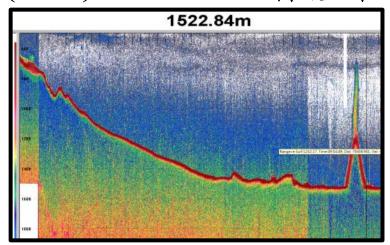
蓬萊斷層帶 (PFZ)



石林隆堆 (GLM)

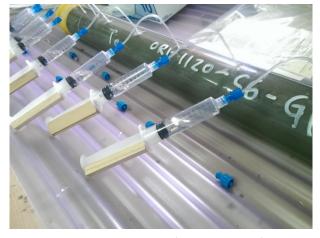


棉花火山 (MHV)



火龍火山1 (FDV-1)

沈積物採樣



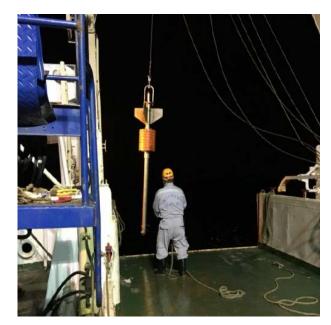
孔隙水取様 (RHIZON)



海研一號



視訊導引岩心採樣系統 (V-Corer)



重力岩心(Gravity Core)



視訊導引抓斗系統 (TV-Grabber)





海水層柱採樣

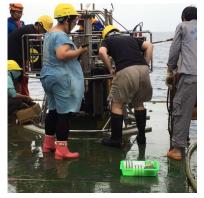






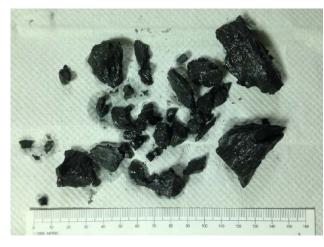
岩心採樣













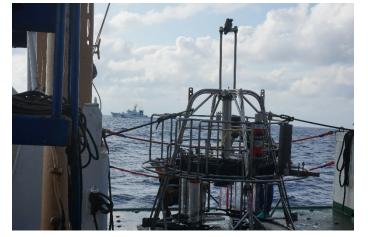
















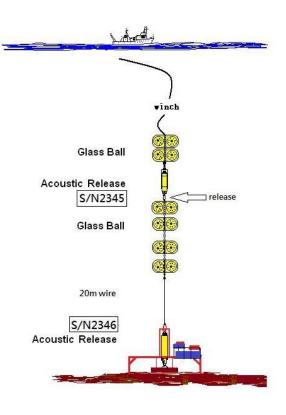


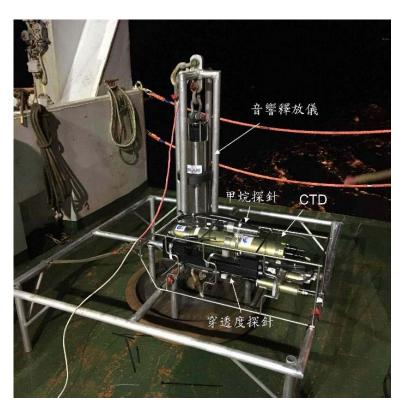






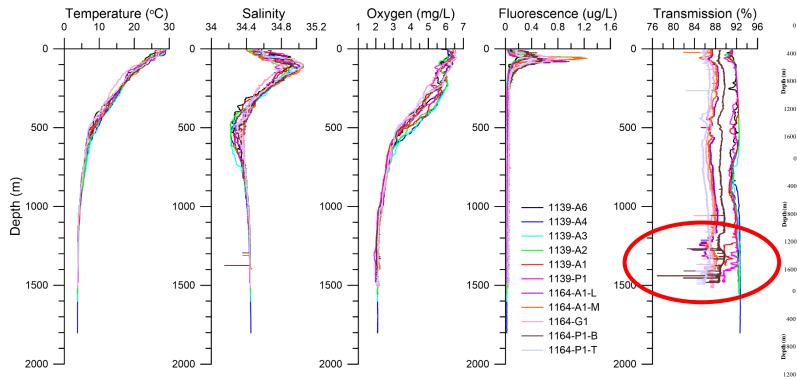








CTD錨碇設備



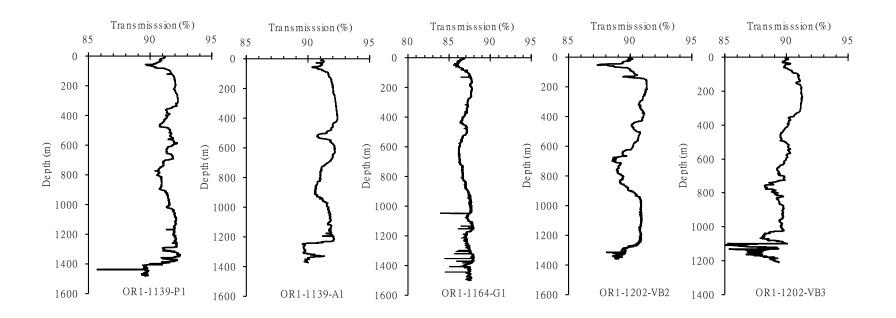
105及106年度各站海水CTD剖面圖。圖中顯示各剖面參數垂直變化相 似,值得注意的是OR1-1139-A1、OR1-1139-P1、OR1-1164-A1-L、 OR1-1164-A1-M、OR1-1164-G1、OR1-1164-P1-B及OR1-1164-P1-T之 透光度剖面,於接近底深深度皆呈現透光度急遽降低現象,顯示測站 深部水體應有高濃度懸浮顆粒水團的存在,推測可能與熱液活動有關。

1200 800

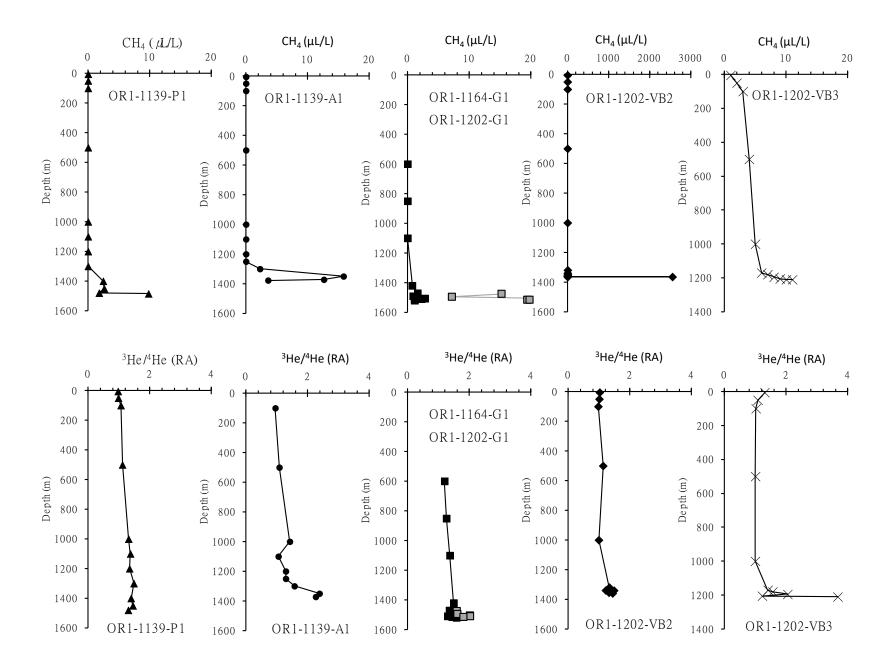
1200

400

107年度各站海水CTD剖面圖→

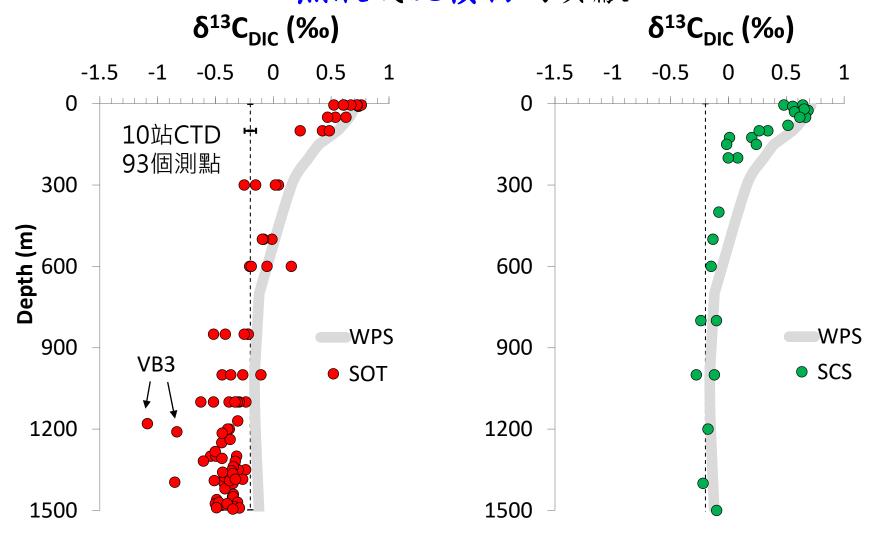


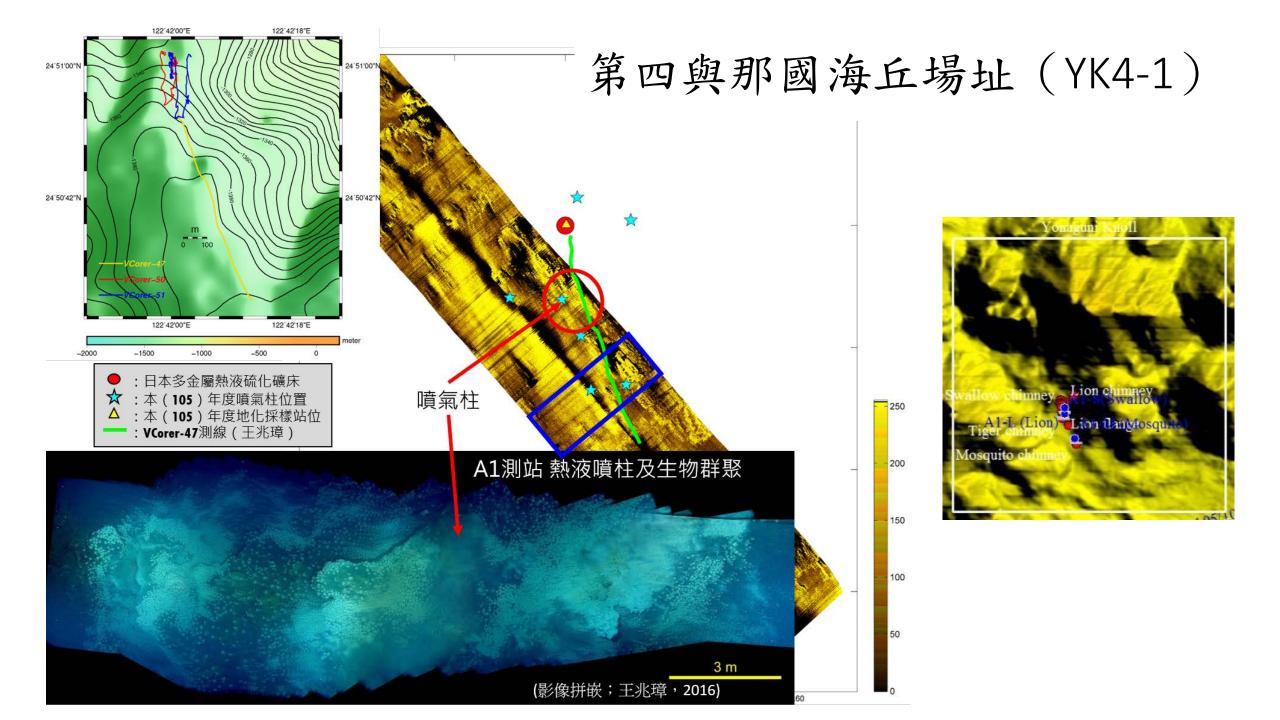
透光度於OR1-1139-P1、OR1-1139-A1、OR1-1164-G1、OR1-1202-VB2及OR1-1202-VB3測站(由左至右)隨海水深度變化圖。



與西菲律賓海 (WPS) 與南海 (SCS) 比較

南沖繩海槽 (SOT) 底水δ¹³C_{DIC}顯著偏負 →熱液或沉積物的貢獻





陳信宏 (2018)

YK4-1 場址





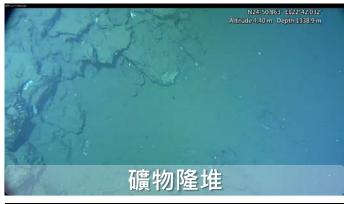




















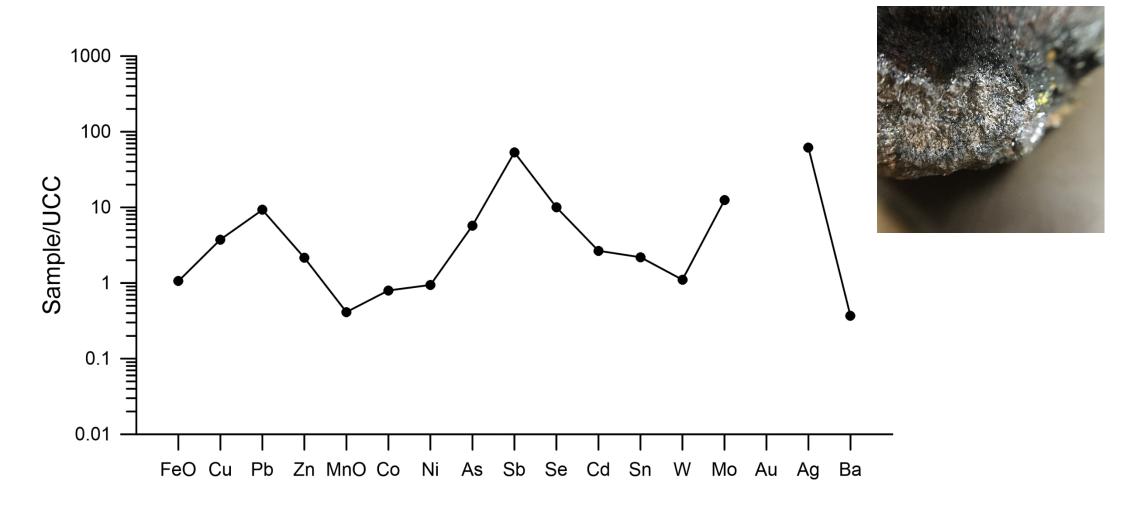


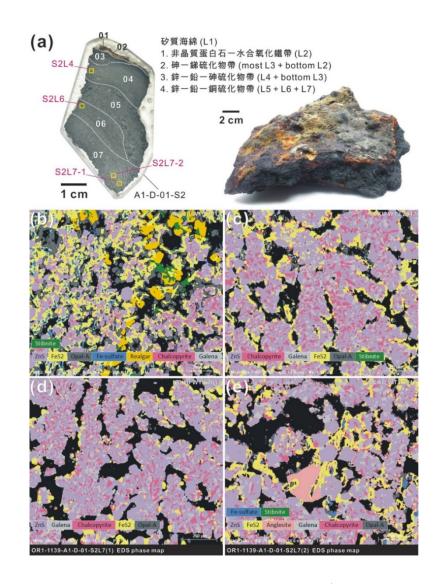






與那國第四海丘 (YK4-1)



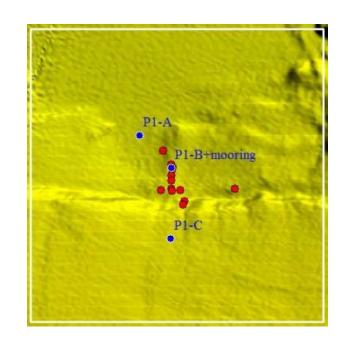


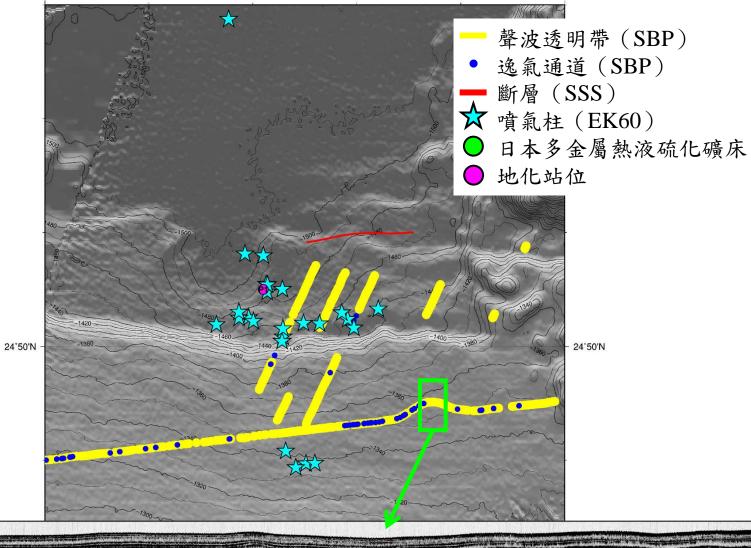
OR1-1139航次底拖鋅-鉛-銅硫化礦石A1-D-01礦物共 生次序。綜合105-106年計畫成果 (江威德,2016)

礦物或化合物	主要成礦期 鋅一鉛一銅 硫化物	成礦晚期 硫化鐵、硫鹽 及二氧化矽	後成礦期 磷酸鹽、氧化物 硫酸鹽、碳酸鹽
閃鋅礦	IS/LSLS	スー乳化物	观
黃銅礦			
方鉛礦		<u> </u>	
纖鋅礦	IS/LS LS		
磁黃鐵礦			
菱硫鐵礦			
白鐵礦			
黄鐵礦			
雄黄			
輝銻礦			
黝銅礦 (含銀, 砷, 鋅)			
斜硫銻鉛礦			
硫砷銻鉛礦			
硫化銀 (螺狀硫銀礦?)			
輝銻銀鉛礦 (fizélyite)			
油雌黄			
雌黄			
硫酸鉛礦			
蛋白石			
白鉛礦			
氯磷鉛礦			
砷銻鉛水合鐵氧化物			
重晶石			
		<u></u> -	
黃鐵礦 (膠狀, 含銀, 錦)			

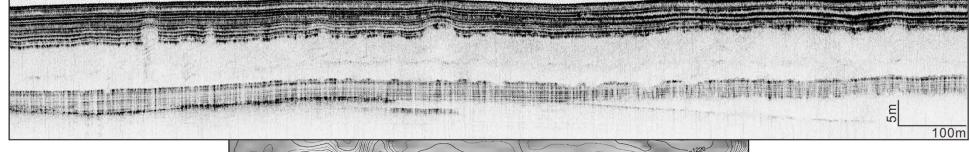
蓬萊斷層帶場址 (PFZ)

122°35'E





122°40'E



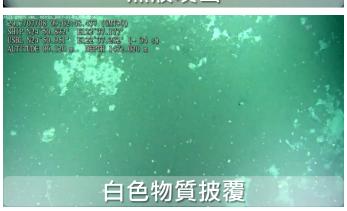
122°35′E

陳信宏 (2018)

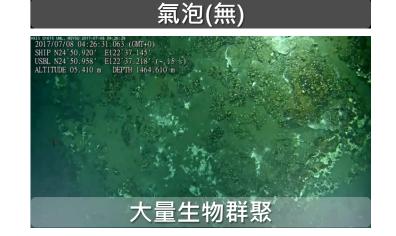
PFZ 場址



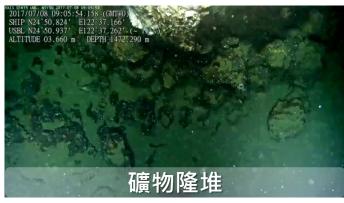








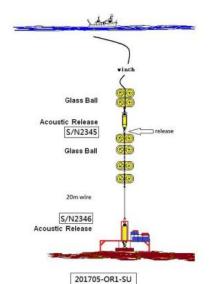






OR1-1164-P1-T-CTD Mooring

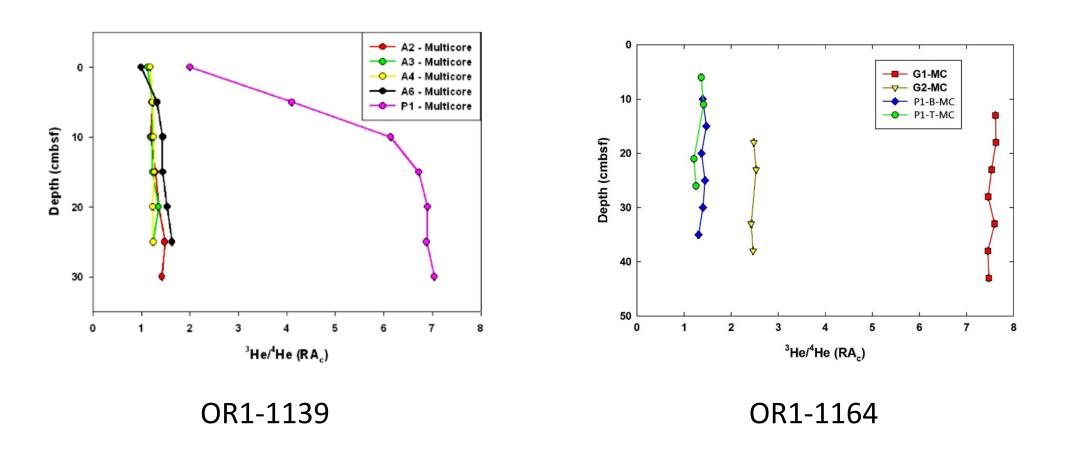




water depth (m) 1492 1488 1484 O 4.12 Lemp 4 3.96 3.96 3.284 3.28 9uo 3.276 3.272 3.268 3.268 Xmission (%) 100 90 80 70 60 **CTD Mooring** 7:00 8:00 8:30 9:00 10:00 7:30 9:30

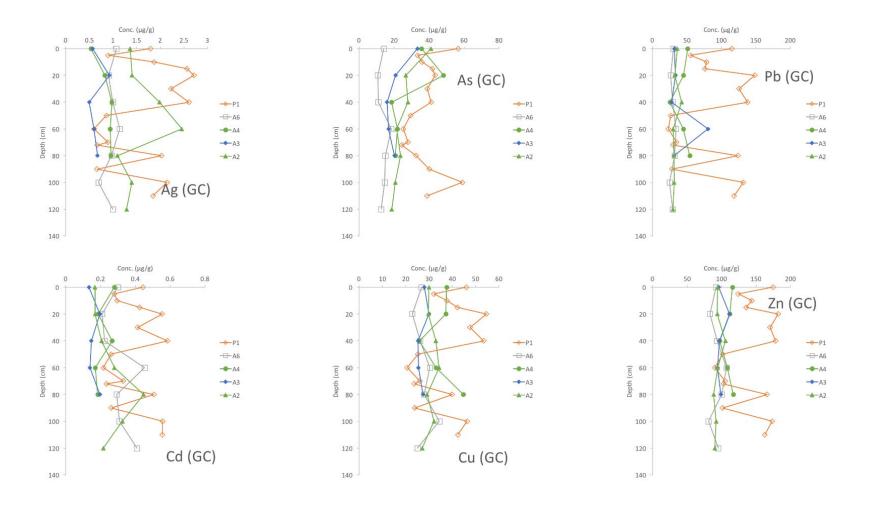
貴儀中心 何文華 技術員設計

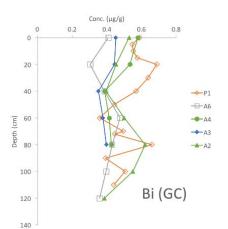
複管岩心沈積物間隙中氦同位素比值



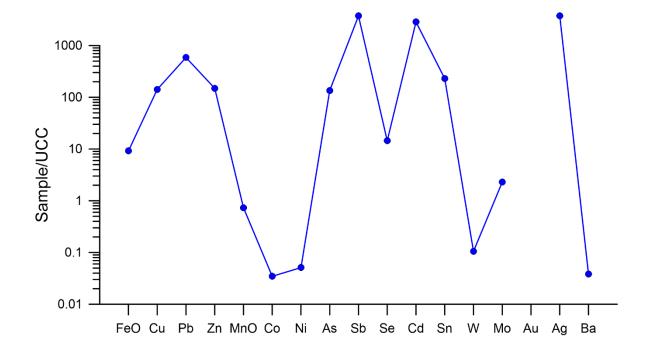
平均西太平洋島弧氦同位素平均值6.4 R_A(Poreda and Craig, 1989)

重力岩心沉積物微量元素濃度垂直剖面變化

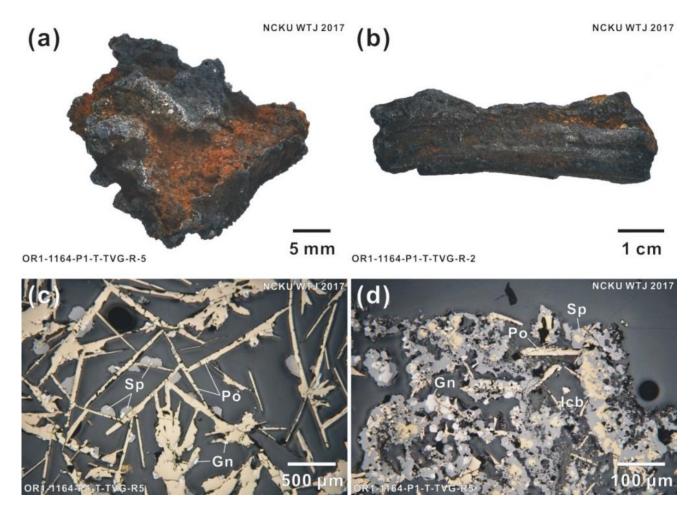




蓬萊斷層帶

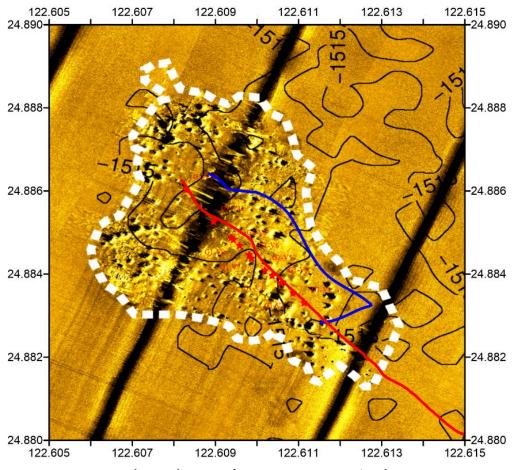


OR1-1139-P1-T

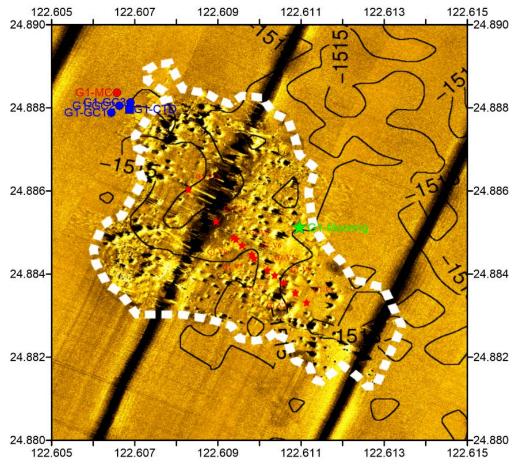


OR1-1164-P1-T-TVG測站鐵一鋅一鉛硫化礦石標本及反光顯微影像。(a)具有管狀通道之礦石;(b)具有硬石膏層之礦石;(c)礦石通道中以磁黃鐵礦(Po)板狀晶體構成片架(cardhouse)組織,另有富鐵閃鋅礦(Sp)和方鉛礦(Gn)蔓生其上;(d)礦石通道外緣由塊狀硫化物組成,方鐵黃銅礦(Icb)為重要礦物之一(江威德,2017)

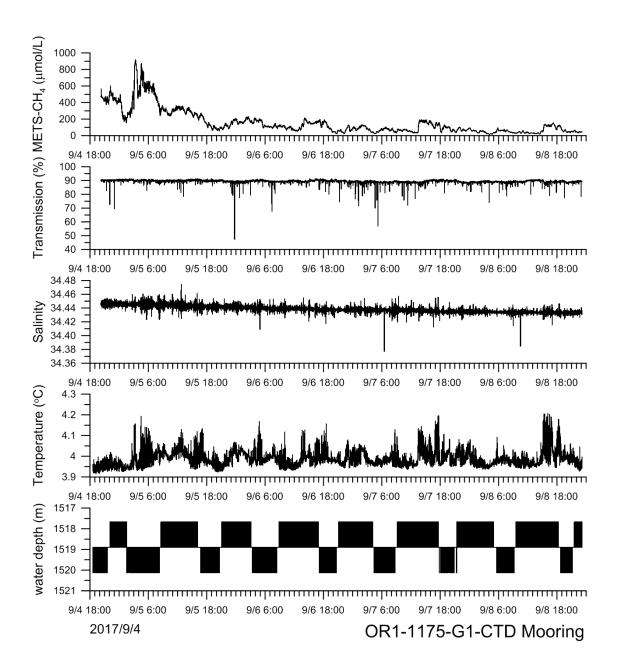
石林隆堆(G1)

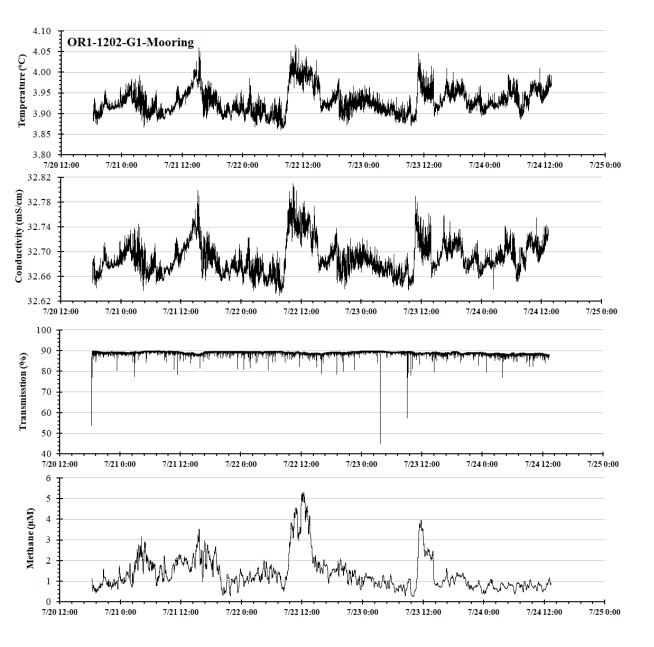


石林隆堆(G1)調查區之底拖作業航跡。紅色星點為視訊導引深海複管式沉積物採樣器之視訊影像確認之煙囪及隆堆位置。藍色線為第一次底拖作業航跡,紅色線為第二次底拖作業航跡。



石林隆堆(G1)調查區各類樣本採樣位置。 藍色方點為CTD及水樣站位,紅色圓點為複管岩心採樣站位,藍色圓點為重力岩心採樣 站位,綠色星形為CTD錨碇站位。





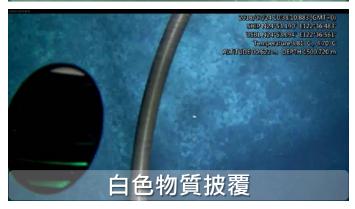
石林隆堆

陳信宏 (2018)

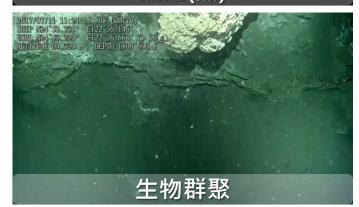
GLM 場址



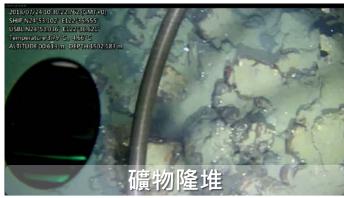






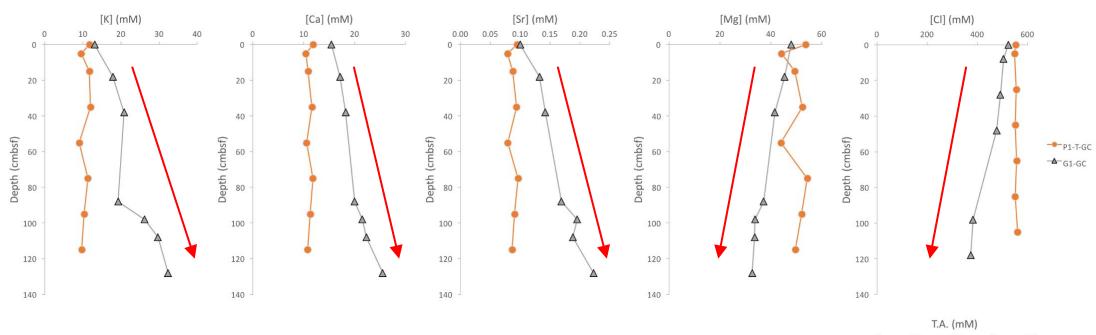




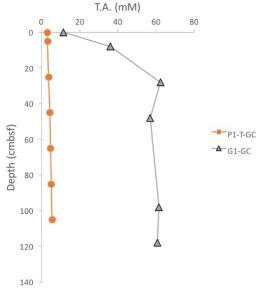




重力岩心間隙水之元素濃度及總鹼度垂直剖面變化



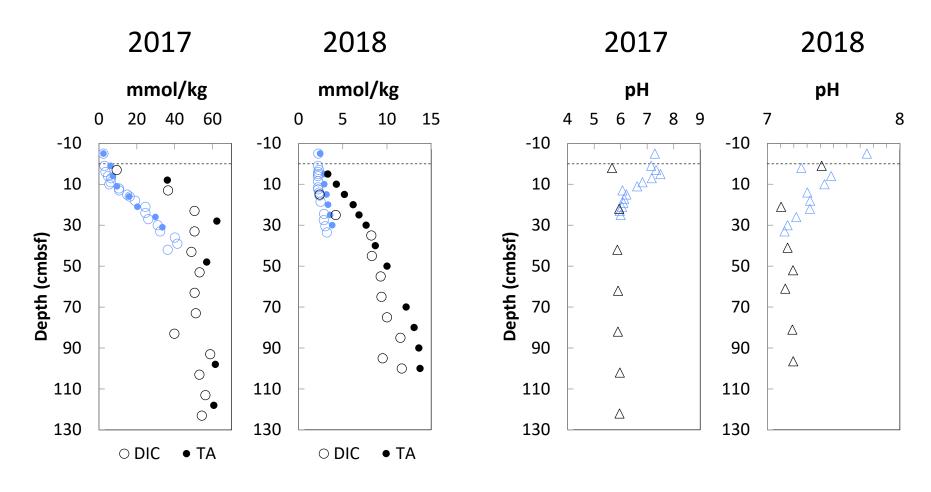
G1站間隙水反應熱液流體訊號,應是氣-液相分離之氣相流體(Cl-濃度低)



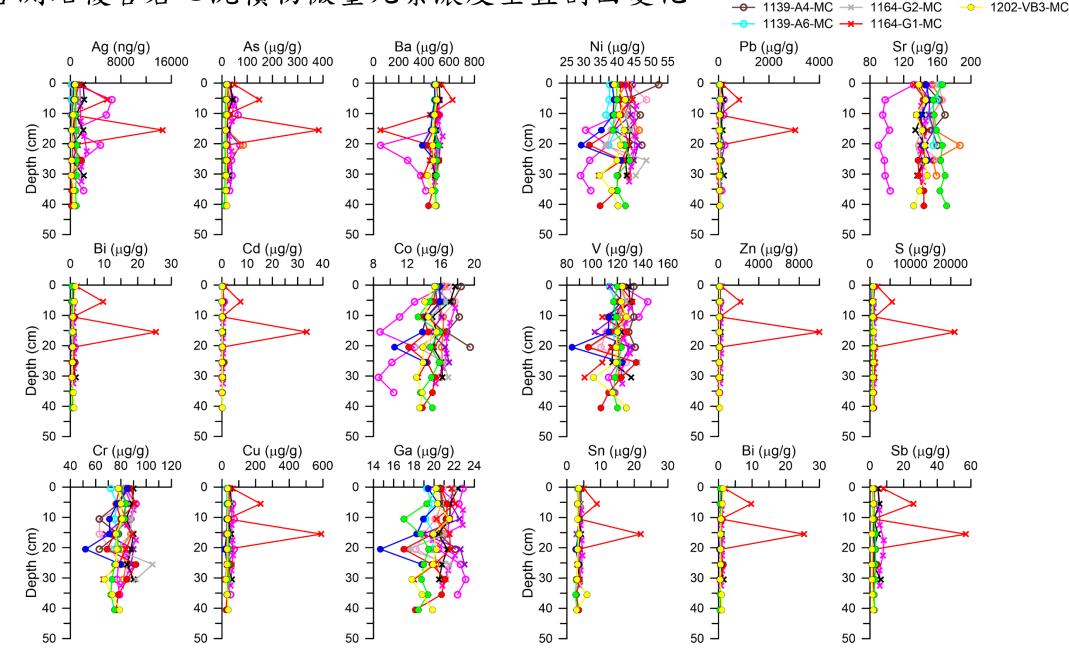
沉積物碳化學:G1站年間變異

2017:顯著碳化學異常(液態CO,浸染)

2018: 與本年度其他站位相似



各測站複管岩心沈積物微量元素濃度垂直剖面變化



--- 1139-P1-MC --- 1164-P1-B-MC --- 1202-G1-MC -× 1164-P1-A-MC

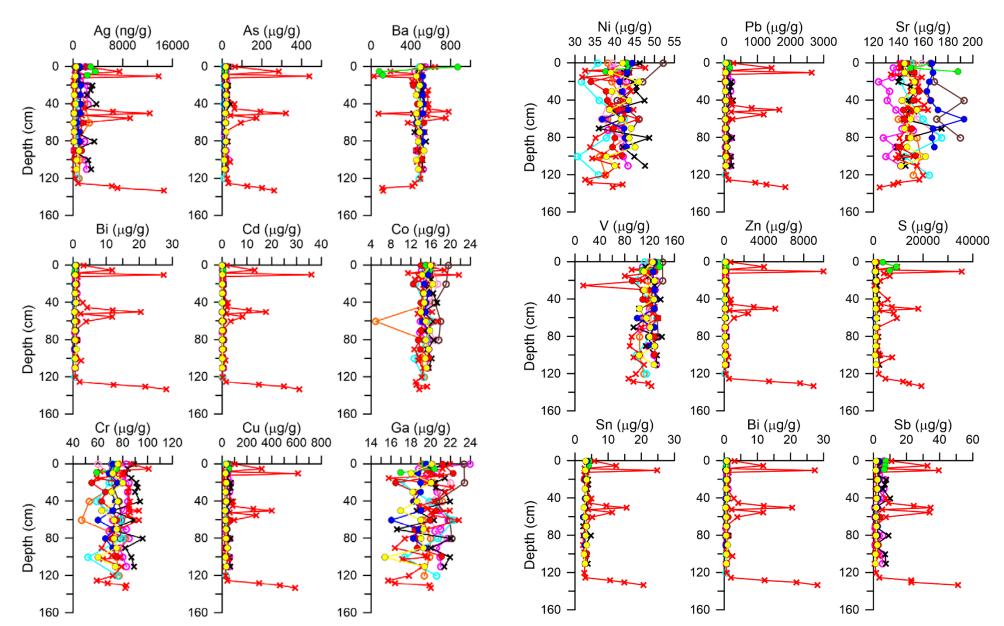
1139-A3-MC → 1164-P1-T-MC

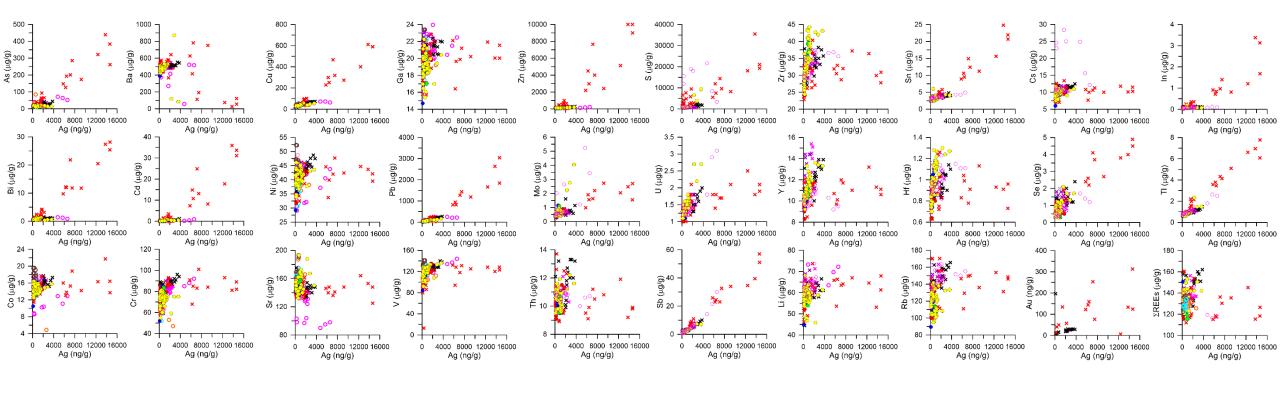
--- 1202-VB1-MC

1202-VB2-MC

各測站重力岩心沈積物微量元素濃度垂直剖面變化

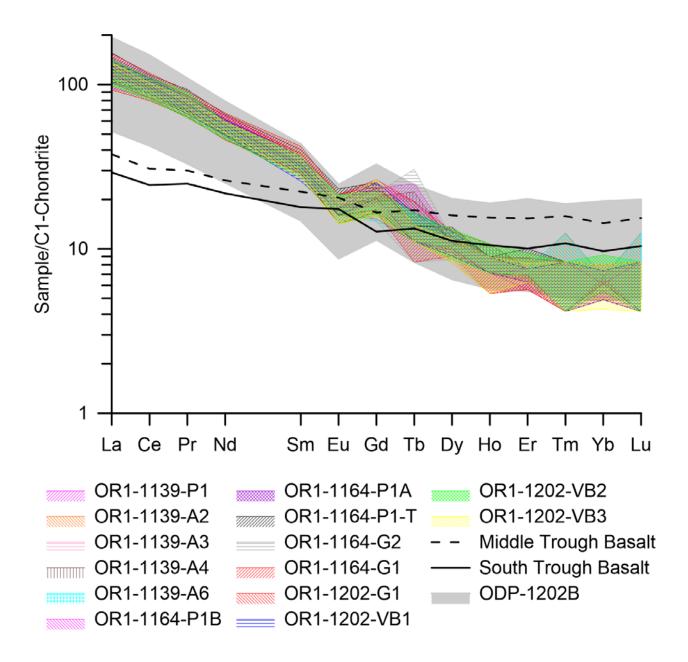


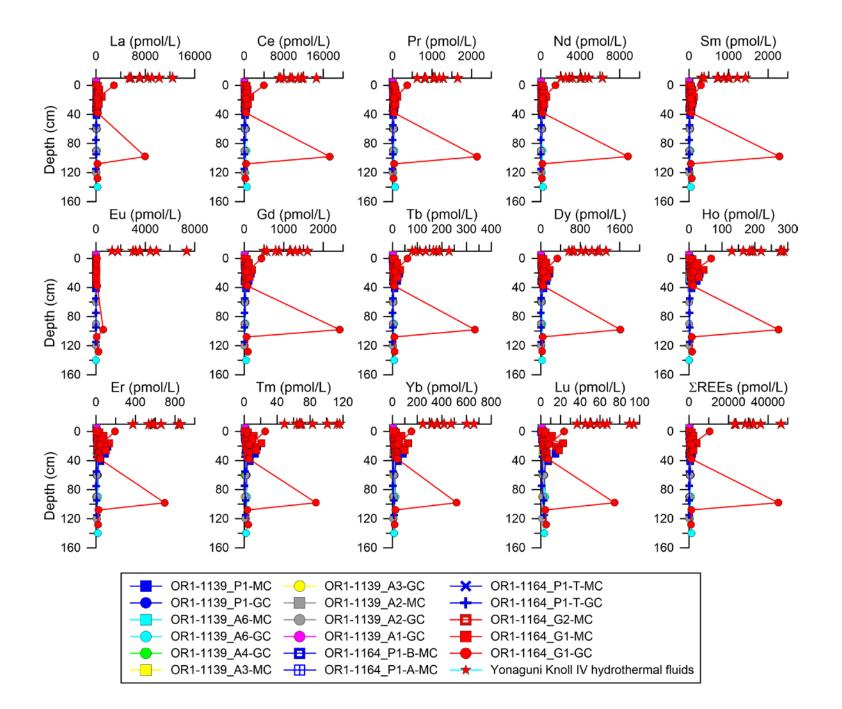




1139-P1
 1139-A6
 1164-G2
 1202-VB1
 1139-A2
 1164-P1-B
 1164-G1
 1202-VB2
 1139-A3
 1164-P1-A
 1202-G1
 1202-VB3
 1139-A4
 1164-P1-T

綜合三年所分析之岩心沈積物樣本As、Bi、Cd、Cu、Pb、Zn、Sn、S、Mo、Sb、Sn、In、Se、Tl、Au與Ag具有高度相關





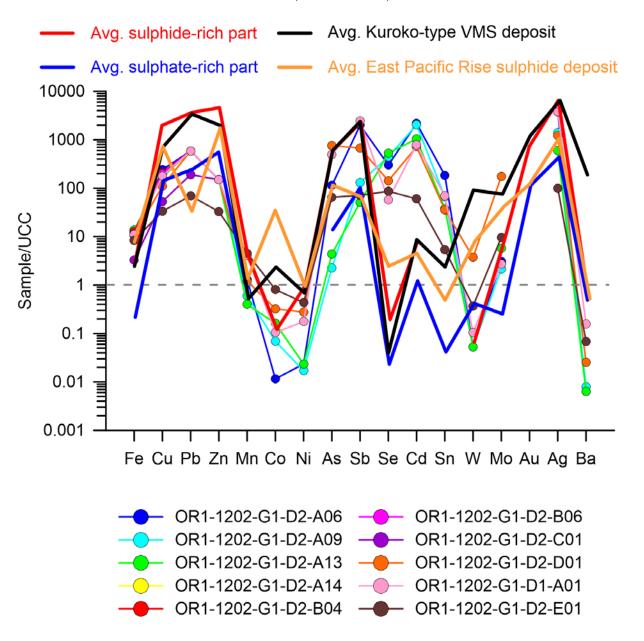




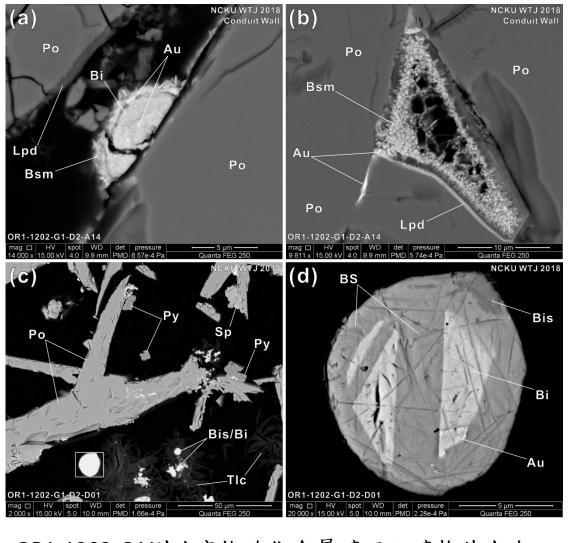


底拖網於石林隆堆站位所取得之岩岩樣

石林隆堆



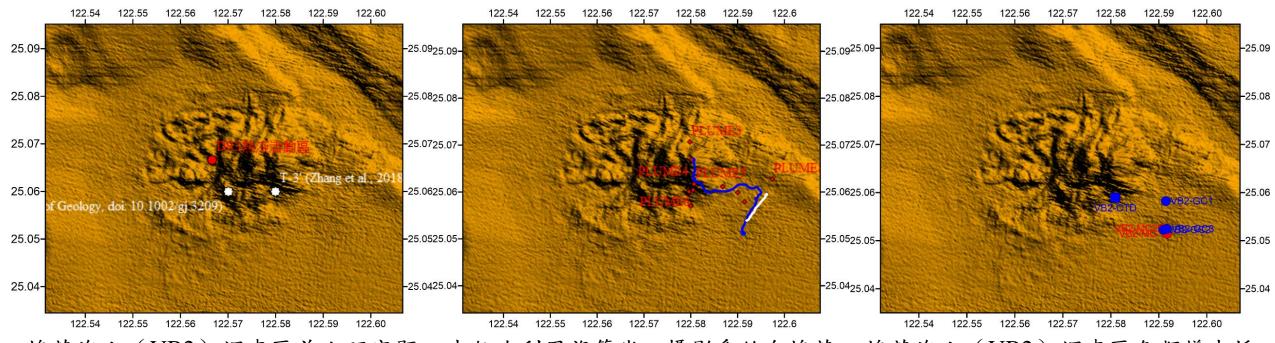




OR1-1202-G1測站底拖硫化金屬礦石之礦物共生次序(江威德,2018)。4C、5C及6C為磁黃鐵礦結構型;VLS、LS和IS分別為閃鋅礦含鐵量及礦物組合所指示之極低度、低度和中度硫化型熱液沉澱條件。

生成礦物	早期
硬石膏	
磁黃鐵礦	6C,5C 4C
斜方砷鐵礦/砷黃鐵礦	40
鋅-銅-鐵硫化物中間固溶體	
方鐵黃銅礦	380-410°C
閃鋅礦/纖鋅礦	VLS, LS (Fe-rich)
方鉛礦	720, 20 (1 0 11011)
黃銅礦	
鈊熔體(鉍-硫熔體)	
自然鉍	
自然金	primary secondary
黃鐵礦	IS ,
白鐵礦	
輝鉍礦,Bi ₂ S ₃	
高鉍硫化物,BiS or Bi₄S₃	? ?
膠狀組織黃鐵礦	
輝銻礦	
雄黃	
纖鐵礦	
氯鉍礦,BiOCI	
滑石/膨潤石	
重晶石	
石膏	
氯磷鉛礦, Pb ₅ (PO ₄) ₃ CI	

棉花海山(VB2)



棉花海山(VB2)調查區前人研究顯 示具有熱液活動潛能。圖中紅色點為 JAMSTEC站位(Lee, 2002), 白色 點為大陸於今年發表之站點(Zhang et al., 2018) •

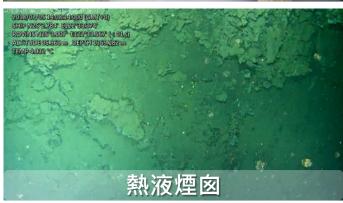
本航次利用複管岩心攝影系統自棉花 海山(VB2)火山往南,然後轉東, 再轉西南進行勘測,沿途發現火山岩 紅色圓點為複管岩心採樣站位,藍色 岩塊、熱液徵兆及生物群聚(紅色點,圓點為重力岩心採樣站位。 USBL定位)。圖中藍色線為海研一 號航跡,白色線為底拖作業期間海研 一號航跡。

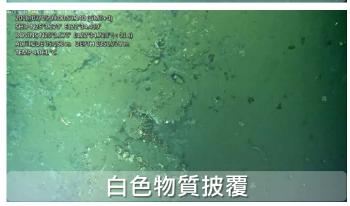
棉花海山(VB2)調查區各類樣本採 樣位置。藍色方點為CTD及水樣站位,

陳信宏 (2018)

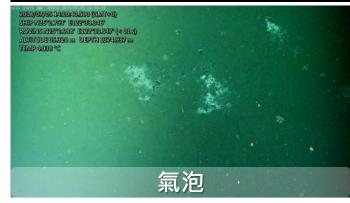
MHV 場址





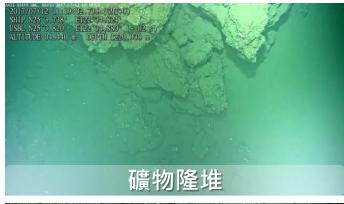






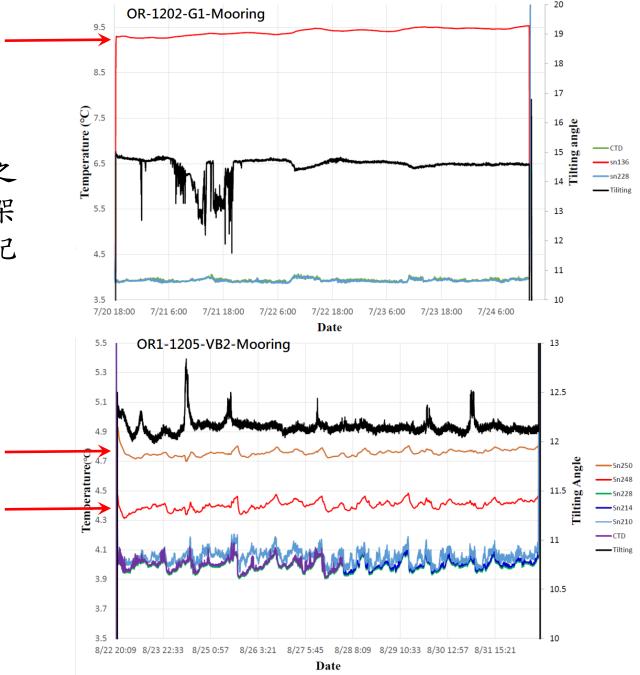


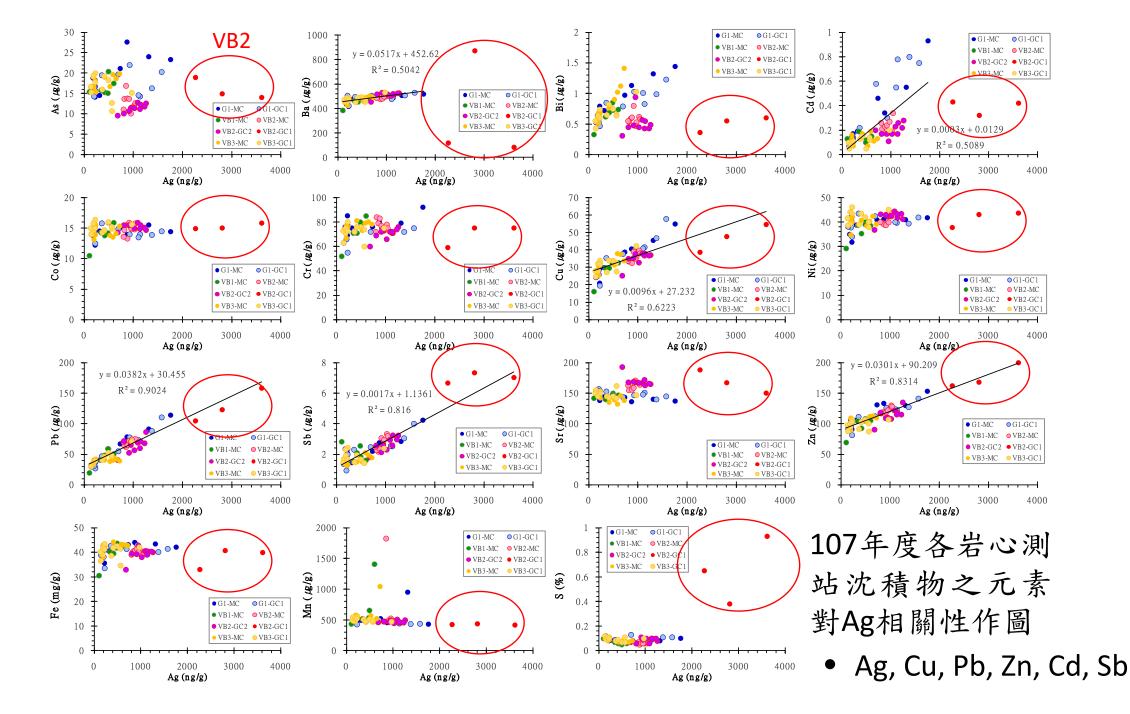






OR1-1202-G1、OR1-1205-VB2 測站之安裝於錨碇架腳的地熱探針、於架頂的傾斜探針及CTD溫度探針時序記錄比對圖。

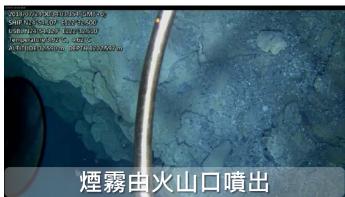




陳信宏 (2018)

FDV-1 場址





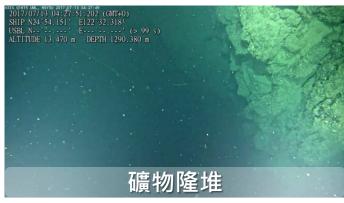


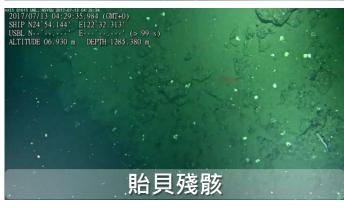
測線總長度	7.83 km
氣泡/熱液/煙囪	3 處
水溫異常	✓
礦物隆堆	63.73 %
白色物質披覆	X
生物群聚	1 處
貽貝殘骸	✓











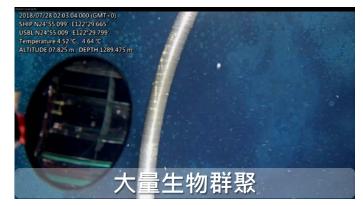
FDV-2 場址



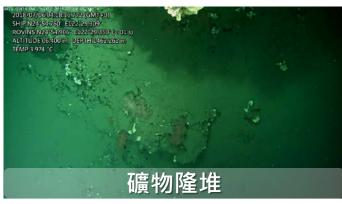






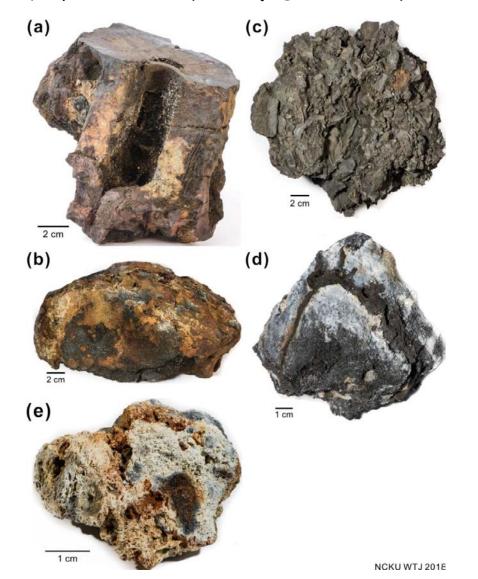


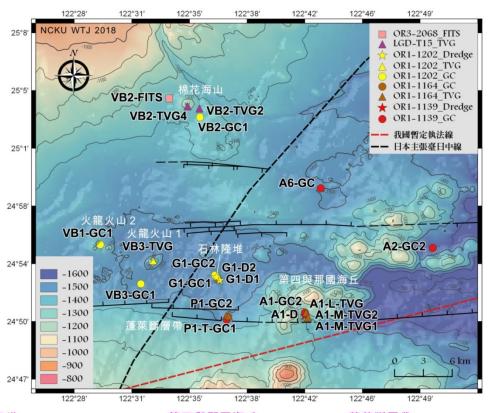






第四與那國海丘鄰近海域熱液礦化之重要特性綜整 (江威德,2018)





石林隆堆

鐵-鋅-鉛硫化礦石 (G1-D2)

極低度至低度硫化型熱液 380-410°C

自然鉍, 輝鉍礦, 原生及次生自然金硬石膏, 磁黃鐵礦, 閃鋅礦, 方鉛礦, 方鐵黃銅礦, 斜方砷鐵礦/砷黃鐵礦

- R 鐵一幹 松油 野 硫化 物 路 推 斷 形
- D. 富硬石膏鐵 鋅 鉛硫化礦

後期局部轉為中度轉硫化型熱液 鐵-鋅硫化礦石 黃鐵礦, 白鐵礦, 膠狀黃鐵礦

C. 鐵-鋅硫化物煙囪角礫斷塊

末期部份轉為相對低溫矽質熱液滑石,膨潤石

硬石膏 (皮殼), 低度硫化型礦物 E. 多孔質富滑石硫化金屬沉澱物

第四與那國海丘

鋅-鉛-銅硫化礦石 (A1-D-01) 低度-中度-高度硫化型熱液 300-350℃

多樣性礦物分帶

鋅鉛砷硫化物帶

砷銻硫化物帶

非晶質蛋白石和水合氧化鐵帶

含銀輝銻銀鉛礦, 膠狀黃鐵礦及 黝銅礦

銅-砷-鋅硫化礦石 (A1-D-12)

中度/高度硫化型熱液 300-350°C

閃鋅礦,方鉛礦,黃鐵礦/白鐵礦, 含銀砷黝銅礦及硫砷銅礦, 重晶石

蓬萊斷層帶

鐵-鋅-鉛硫化礦石 (P1-T-TVG) 極低度至低度硫化型熱液 350-400°C

硬石膏,磁黃鐵礦,閃鋅礦, 方鉛礦,方鐵黃銅礦

棉花海山

鋇-鋅-鉛硫化礦石 (VB2-TVG2)

中/高度硫化型熱液 重晶石, 閃鋅礦, 方鉛礦, 雄黃, 蛋白石

鐵-鋅-銅硫化礦石 (VB2-TVG4)

中度硫化型熱液 黃鐵礦,白鐵礦,閃鋅礦,黃銅礦, 方鉛礦