Cruise Report
Investigation of the Cocos-Nazca Spreading Center

The Transition from Rifting to Seafloor Spreading at the Western Tip of the Cocos-Nazca Rift

R/V Sally Ride Leg 1806
Manzanillo, Mexico to San Diego, California, April 20, 2018 – May 26, 2018

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1. Executive Summary

Aboard *R/V Sally Ride* (Leg 1806), from April 20 to May 26, 2018 (23 science days), we performed geophysical surveying and rock sampling along the western portion of the Cocos-Nazca (C-N) spreading center (Figures 1 and 2). Our overall goal was to elucidate the development of magmatic seafloor spreading in the vicinity of the Galapagos Triple Junction, where the western tip of the C-N Rift is rifting ~0.5 Ma crust accreted on the east flank of the East Pacific Rise (EPR) near 2°15'N. We collected bathymetric, magnetic, and gravity data over a total of ~10 days of geophysical surveying, covering a V-shaped area extending eastward from the Hess Deep Rift to ~98.5°W and including on- and off-axis terrane not previously surveyed. The survey also included collecting magnetic and gravity data across the Galapagos microplate to understand its initiation and evolution. We also performed a total of 66 dredges (3 empty) over a total of ~13 days, including 60 dredges along the C-N rift and adjacent EPR, three dredges on the Dietz Volcanic Ridge, one southeast of the Dietz Volcanic Ridge, and one at the southern triple junction with the EPR at 1°10'N. Our final dredge was conducted on the EPR at 3° 38'N as we left the study area to transit to San Diego. On shore, the geophysical data and samples will be analyzed to shed light on the initiation and evolution of seafloor spreading.

Our science party comprised a diverse international group of undergraduate and graduate students and research scientists from Poland, Spain, Russia, and the UK, as well as the US. During our cruise, we posted regular updates on our cruise blog and social media, which was followed by people around the world. We are grateful to the National Science Foundation for funding this work, and to InterRidge and the University of Leeds for providing support for a number of our international science party members. We are also grateful for the extraordinary work of the Captain and crew of *R/V Sally Ride*, whose efficiency and good cheer made our cruise such a success.

2. Introduction

A fundamental question in the study of mid-ocean ridges focuses on how spreading centers initiate and evolve in different settings [e.g., *Bonatti*, 1985; *Lonsdale*, 1989; *Manighetti et al*., 1997; *Taylor et al*., 1995; *Van Wijk and Blackman*, 2005]. A related question is how the dominant style of tectonic segmentation observed along a particular ridge is established, and its relationship to the initial rifting configuration [e.g., *Augustin et al*., 2014; *Bonatti*, 1985; *Ligi et al*., 2012; *Schouten et al*., 1985; *Taylor et al*., 1995]. While most rift-to-drift studies focus on rifting of continental lithosphere, the Galapagos Triple Junction (GTJ) region offers an opportunity to examine these questions in an oceanic setting, which may serve as a complement to studies of continental rifting.

To address these questions, we conducted a research cruise on the *R/V Sally Ride* (Leg 1806) from April 20 to May 26, 2018 in the area of the GTJ (Figure 1). Our goal was to elucidate the development of magmatic seafloor spreading at the GTJ, where the western tip of the Cocos-Nazca (C-N) Rift is rifting ~0.5 Ma crust accreted on the east flank of the East Pacific Rise (EPR) near 2°15'N [*Lonsdale*, 1988]. The result is a V-shaped topographic gore with its apex close to the axis of the East Pacific Rise widening to the east to reflect the spreading between the

Cocos and Nazca plates. This gore contains a chain of spreading segments that presents an opportunity to study each stage in the transition from rifting to magmatic seafloor spreading [Smith and Schouten, 2018]. The study area also allows us to examine progressive stages in the establishment of tectonic and magmatic segmentation along this intermediate-spreading ridge. Our overall goals were twofold: 1) to elucidate the changes in - and the interplay between - tectonic and magmatic processes that occur from initial rifting through full magmatic seafloor spreading, and 2) to investigate the development and evolution of the tectonic and magmatic segmentation characteristics of this intermediate-rate spreading center.

Aboard *R/V Sally Ride* (Leg 1806), from April 20 to May 26, 2018 (23 science days), we performed geophysical surveying (collecting bathymetry, magnetic and gravity data) and rock sampling (by dredging) along the western portion of the Cocos-Nazca (C-N) spreading center and the East Pacific Rise. We also collected geophysical data over the Galapagos microplate and sampled near and along the Dietz Volcanic Ridge. The scientific party and outstandingly able crew are listed in Appendix A, and a daily diary of our activities is presented in Appendix B.

3. Tectonic History and Previous Work

At the Galapagos triple junction, the C-N Rift does not meet the EPR in a true Ridge-Ridge-Ridge (RRR) configuration (Lonsdale, 1977, 1988; Schouten et al., 2008; Searle & Francheteau, 1986; Smith et al., 2013; Smith et al., 2011; Zonenshain et al., 1980); instead the Rift tip stops ~25 km east of the EPR axis (Figure 1). Two secondary rifts do link with the EPR forming true RRR triple junctions. In the south at 1°10'N, Dietz volcanic ridge intersects the EPR and presently forms the southern boundary of the Galapagos microplate. To the north, Incipient Rift intersects the EPR at 2°40'N to form the northern triple junction (Klein et al., 2005; Lonsdale, 1988; Lonsdale et al., 1992; Schouten et al., 2008; Smith et al., 2013; Smith et al., 2011).

Schouten et al. (2008) identified a succession of older rifts northeast of Incipient Rift, and concluded that Incipient Rift is just the latest of a sequence of southeast-trending cracks that jumped southwestward during the last 5 Ma, each accommodating some minor extension of EPR-generated crust (Figure 1). The western tips of these cracks mark the trace of the northern triple junction. Schouten et al. (2008) explained the transient rifts using a crack interaction model, which would indicate that in the last 5 Ma the C-N Rift tip has remained at a variable distance to the EPR of 20-50 km. This model also predicts that cracking should be symmetric about the C-N Rift tip. Subsequently, Smith et al. (2011) documented a similar succession of transient rifts that formed southeast of the Galapagos microplate between 2.5 and 1.5 Ma. At ~1.4 Ma, however, extension became fixed on the last of the southern cracks and the Galapagos microplate developed (Smith et al., 2013).

As the C-N Rift propagates westward it produces a v-shaped area of seafloor bordered by the large, initial faults that cut the ~0.5 Ma EPR lithosphere (C-N gore, Holden and Dietz (1972)). Searle and Francheteau (1986) noted an extensional rift basin located west of Hess Deep rift and offset ~2 km north. This 12-km-long basin represents the earliest stage of rifting behind the Rift tip. Its current bounding faults will become the gore border scarps. The segment east of this basin is Hess Deep rift. It is ~25 km long, and displays significant changes in morphology along its axis. A deep basin in the western half of the segment reaches water depths of 5400 m and

contains isolated areas of volcanic relief (Lonsdale, 1988). In the eastern half, more voluminous eruptions have built an axial volcanic ridge ~11 km long and up to 500 m high. From west to east along the AVR, water depths shallow from ~4800 m to ~4100 m. Lonsdale (1977) and Searle and Francheteau (1986) suggested that seafloor spreading begins within Hess Deep rift.

Intrarift ridge (IRR) is located on the northern side of the Hess Deep rift and inward of the gore scarps. It extends ~20 km along the axis. Deep crustal and upper mantle rocks have been sampled from its top and slopes. The IRR has been studied for over two decades, and two expeditions (ODP Leg 147 and IODP Leg 345) drilled the IRR with the goal of understanding the structure and architecture of the lower crust and mantle exposed in this region (e.g., Francheteau et al., 1990; Gillis, Mevel, et al., 1993; Gillis et al., 2014; Hekinian et al., 1993; Karson et al., 2002; Lissenberg et al., 2013; Lonsdale, 1977; MacLeod et al., 1996; Rioux et al., 2012; Searle & Francheteau, 1986; Stewart et al., 2002; Stewart et al., 2003).

Prior to our cruise, chemical analyses have been reported for only eight sampling sites along the 350 km length of ridge between about 98°W and 101.5°W. These samples were recovered during expeditions in the 1980s of the R/V Trident, R/V Sonne, and R/V Jean Charcot [Hekinian et al., 1993; Puchelt and Emmermann, 1983; Schilling et al., 1982]. Additional sampling sites along Hess Deep rift – without reported chemical analyses – were collected during a Nautile dive in 1988 [Francheteau et al., 1990] and are archived in Brest (M. Cannat, pers. Comm).

4. Bathymetric, Magnetic, and Gravity Data Collected

Bathymetric and sidescan data are presented in Figures 3 and 4. Bathymetry data were collected using a Kongsberg EM122 multibeam echosounder giving an ~10 km-wide swath of data – depending on water depth. The surveys were run at 10.5 kt, on average. The data were acquired with Kongsberg SIS software (Seafloor Information System, v 4.3.2). A second SIS survey was started when the grid engine had errors, with this resulting in a rawdata b file set. A third SIS survey was started after SIS crashed and was restarted. The raw EM122 data were gridded using MBSystem software and both bathymetry and sidescan netcdf files were generated. The gridded data were displayed using GMT software, Fledermaus, and QGIS. The netcdf files generated by MBSystem had to be converted to Golden Software Binary Grid format in QGIS to be viewed in Fledermaus. QGIS was the best option for viewing the sidescan grids. The MBSystem scripts used to process the data is given in Appendix C.

Sippican XBT (expendable bathythermograph) drops acquired data to calculate sound velocity profiles for input to the EM122 using Turo hardware and software. XBTs were generally taken every day when collecting EM122 data.

Magnetic anomaly data are presented in Figures 5 and 6. The magnetic field was measured with a Marine Magnetics SeaSPY manufactured by Marine Magnetics. The SeaSPY magnetometer data were collected using BOB software. Towfish 13186 was used, and initially towed about 250m behind the ship. For the second survey, it was towed 233m behind the ship. For the third survey, it was towed 300m behind the ship. Subsequent surveys were towed at 300m behind the ship. A second Towfish was used after the last dredge on the leg back to San Diego, because the

first Towfish wasn't working after it was recovered and brought on deck without turning it off. The final deployment on 5/18 was performed with towfish 13189, which took several power cycles to collect data and briefly lost contact on 5/19. The magnetometer was towed at full survey speed (~10.5 kt) throughout its deployment. The processed along-track magnetic data, plotted on the bathymetry data using GMT for the C-N Rift and Galapagos microplate, are shown in Figures 4 and 5.

Processed gravity data are presented in Figures 7-13. Gravity was measured with a Bell Aerospace BGM-3 gravimeter housed on the First Platform Level in the forward, starboard section of the deck. A gravity tie was obtained in San Diego before the ship departed, in Manzanillo, and will be obtained on arrival in San Diego on May 26. The data were processed in a number of steps described in the Appendix.

5. Rock Sampling: Collection, Description and Archiving

Dredge locations are presented in Figures 8 and 9 and described in Table 1. A total of 66 dredges were performed, of which 63 recovered rock samples. The majority were sited along the Cocos-Nazca spreading axes, three were cited on elevated crustal blocks between the ends of Cocos-Nazca spreading centers, three were sited on the adjacent EPR, one was sited near the large volcano south east of Dietz volcanic ridge, three were sited on the Dietz volcanic ridge, and one near the intersection of the Dietz volcanic ridge and the EPR. A final dredge was sited on the EPR north of the Incipient Rift. Notably, we dredged without using a "pinger' on the wire because the HiPAP transducer brought to sea could not be operated over the spatial range needed for dredging. Instead, we found that it was quite straight-forward to identify when the dredge had landed on/lifted off the seafloor by observing the decrease/increase in wire tension, in conjunction with a knowledge of the bathymetry and wire out.

The vast majority of axial dredges recovered basalts with fresh or somewhat altered glass. The three dredges on the elevated crustal blocks recovered older basalt or in one case metabasalt. Many of the basalts recovered were strikingly porphyritic.

The rocks within each dredge were examined and one or more visually distinct rock types within each dredge were identified (based on morphology, weathering, phenocryst content, etc.). From within each rock type, one or more representative samples were selected, numbered, and described in greater detail (Table 2). Each numbered sample was further subsampled (whenever sufficient material was available). In general, if the sample included glass, the glass was spalled or chipped off and collected; the crystalline whole rock was cut into two slabs with a rock saw (one slab for whole rock analysis, one to make a thin section); and a representative portion of the remaining sample was collected as 'hand sample'. Samples of manganese crusts and metabasalts were also collected and archived by Iker Blasco del Barrio, Sara Afshar, Dominik Zawadzki and Joe Cann (Table 3). Remaining rocks from each dredge were stored in buckets to be archived at the Scripps Institution of Oceanography Geological Collections Repository.

Numbering of dredges and samples:

For convenience while at sea, dredges were numbered with the ship, leg, and dredge number (e.g., SR1806-D1 designating RV Sally Ridge Leg 1806, dredge 1). Individual samples selected and described from each dredge were designated with an additional number (e.g., SR1806-D1-1 designates sample 1 from dredge 1). In addition, prior to setting sail, we obtained IGSN numbers to be used for all dredges and described samples. The correspondence between our own numbers and the IGSN numbers is shown in Table 1.

6. Outreach During Cruise

During our cruise we maintained a cruise website (http://blogs.nicholas.duke.edu/cocosnazca/) where we posted "Dispatches from Sea" on an almost daily basis. We also maintained accounts on Twitter (https://twitter.com/cocos_cruise) and Instagram (https://www.instagram.com/cocos_cruise/). In addition, the Sally Ride has a twitter feed that linked to ours and drew from our posts. We know that at least one middle school class followed our posts and communicated with us by email.

The posting that received the most traffic was that describing our participation in a 'rescue at sea' when we came to the aid of two men sailing from Tahiti on a catamaran with a broken mast and little fuel and food. This event was also picked up by some media (San Diego Union Tribune) and the Duke Chronicle.
www.sandiegouniontribune.com/news/.../sd-me-sallyride-rescue-20180501-story.html
https://scripps.ucsd.edu/expeditions/sallyride/2018/04/30/sally-ride-to-the-rescue/

7. Archiving of Data and Samples

Data and samples will be archived as described in our proposed data management plan. Raw and processed geophysical data will be archived respectively at NCEI and MGDS. For rock samples collected, we obtained IGSN numbers to be used for all dredges and described samples. The correspondence between our own cruise numbers and the IGSN numbers is shown in Table 2. The remaining samples from all dredges, comprising approximately seventy 5-gallon buckets, were sent to the Scripps Institution of Oceanography Geological Collections Repository (see column 'Notes to Scripps' in Table 2).

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9. Figures

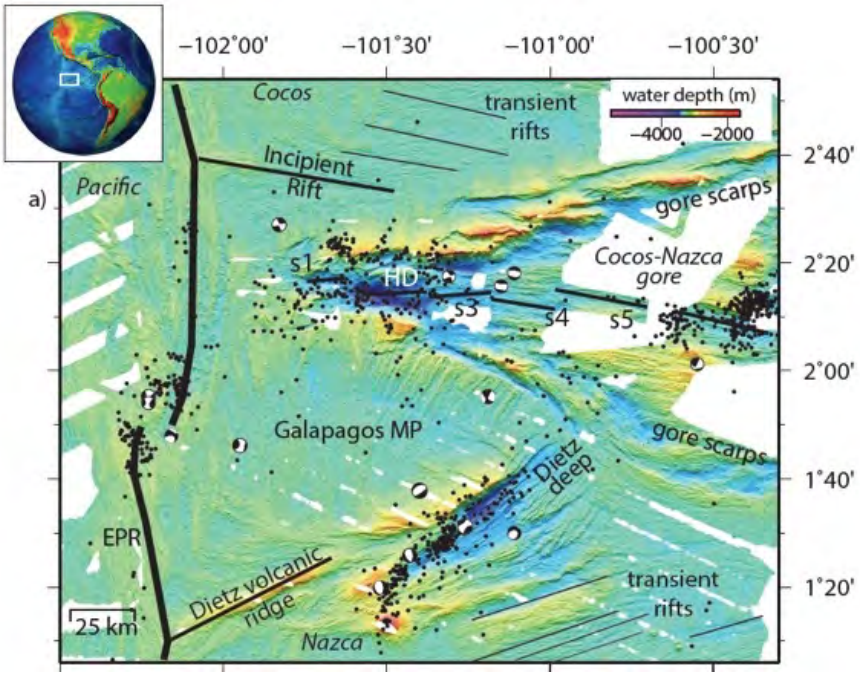

Figure 1. Bathymetry of the western tip of the Cocos-Nazca Rift. Black dots: hydrophone-recorded earthquakes (Fox et al., 2001). Beach balls: focal mechanisms of teleseismically-recorded earthquakes (Ekström et al., 2012). Thick black lines: plate boundaries. Thin black lines: area of transient rifts (Schouten et al., 2008; Smith et al., 2011). Rift segments labeled. HD: Hess Deep rift. EPR: East Pacific Rise. MP: microplate. Figure from Smith and Schouten 2018; *does not include data collected during the cruise reported here*.

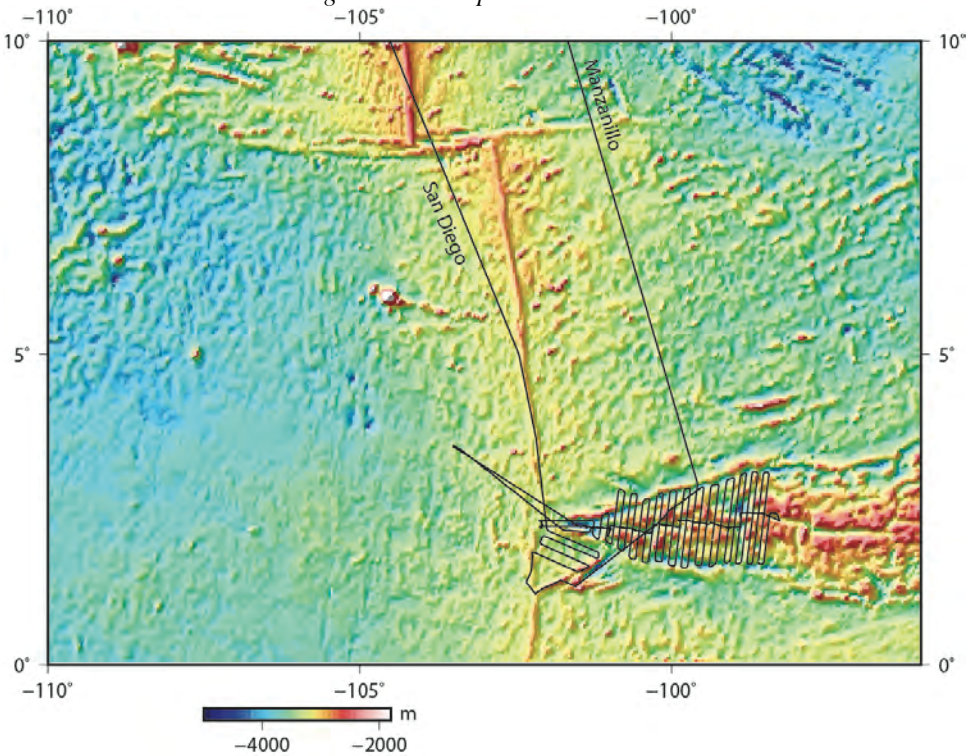

Figure 2. Cruise track. Note the excursion northwest of study area to aid ship in distress.

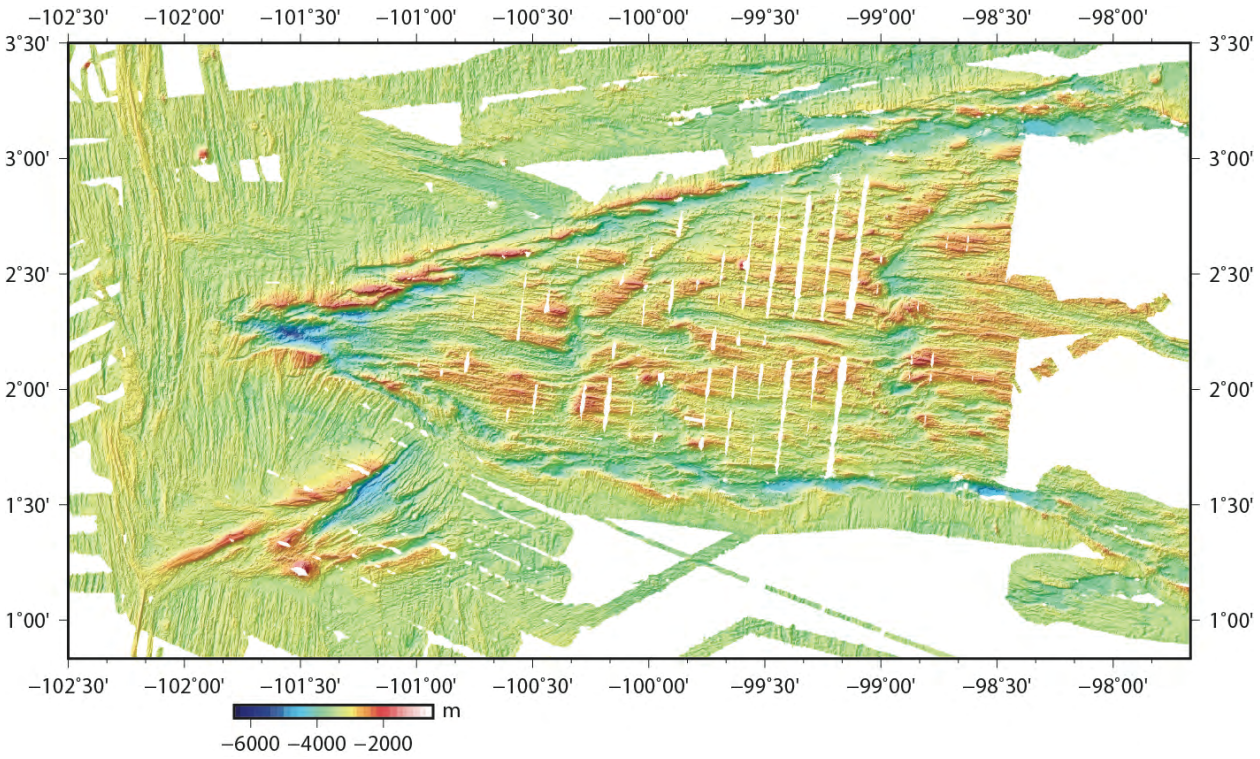

Figure 3. Bathymetric data collected during our cruise combined with data from previous studies.

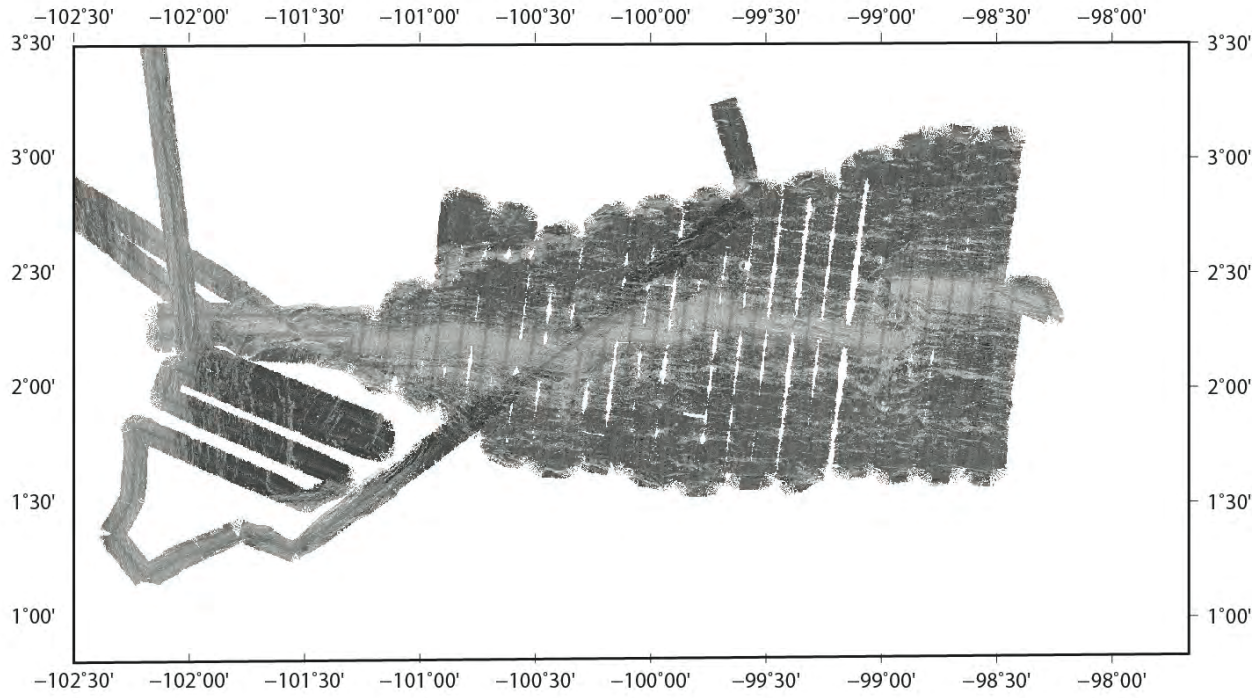

Figure 4. Sidescan sonar data derived from the EM122 data collected during our cruise.

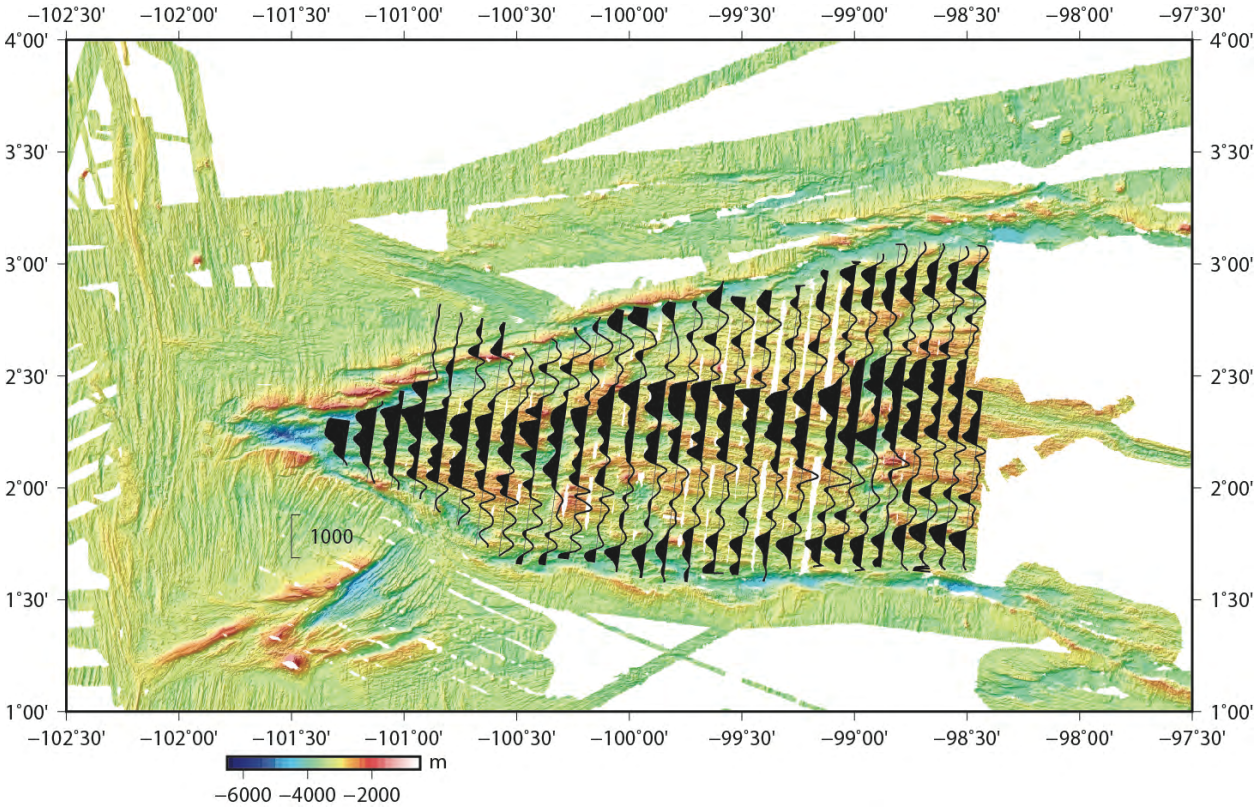

Figure 5. Magnetic anomaly data collected over the Cocos-Nazca spreading center. Black on the figure represents negative anomalies, corresponding broadly in this survey with normally magnetized crust.

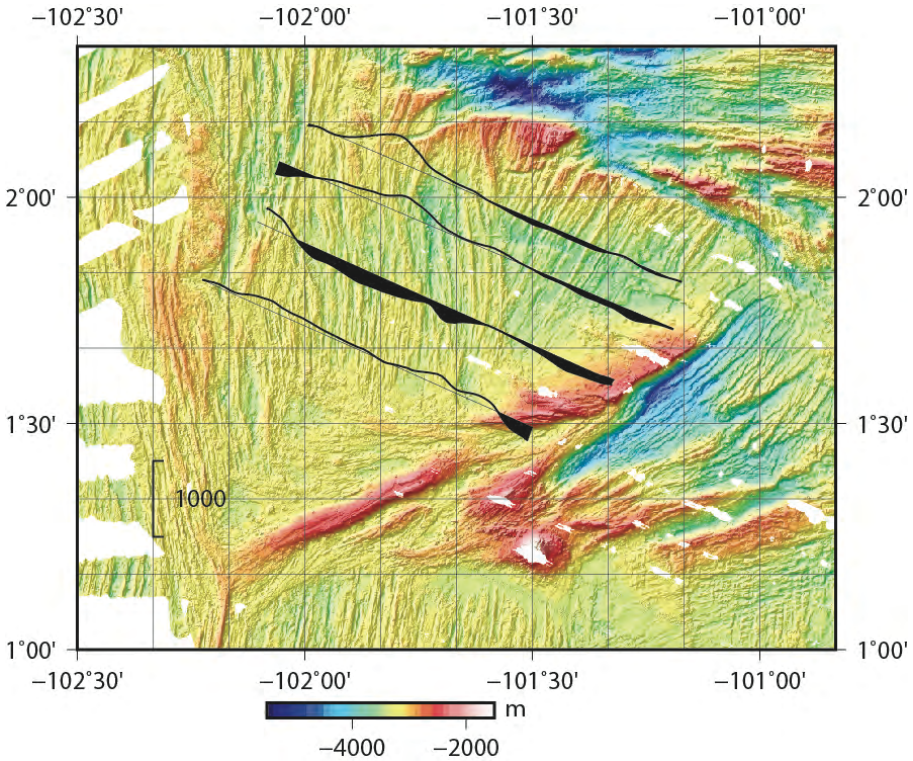

Figure 6. Magnetic anomaly data collected over the Galapagos Microplate.

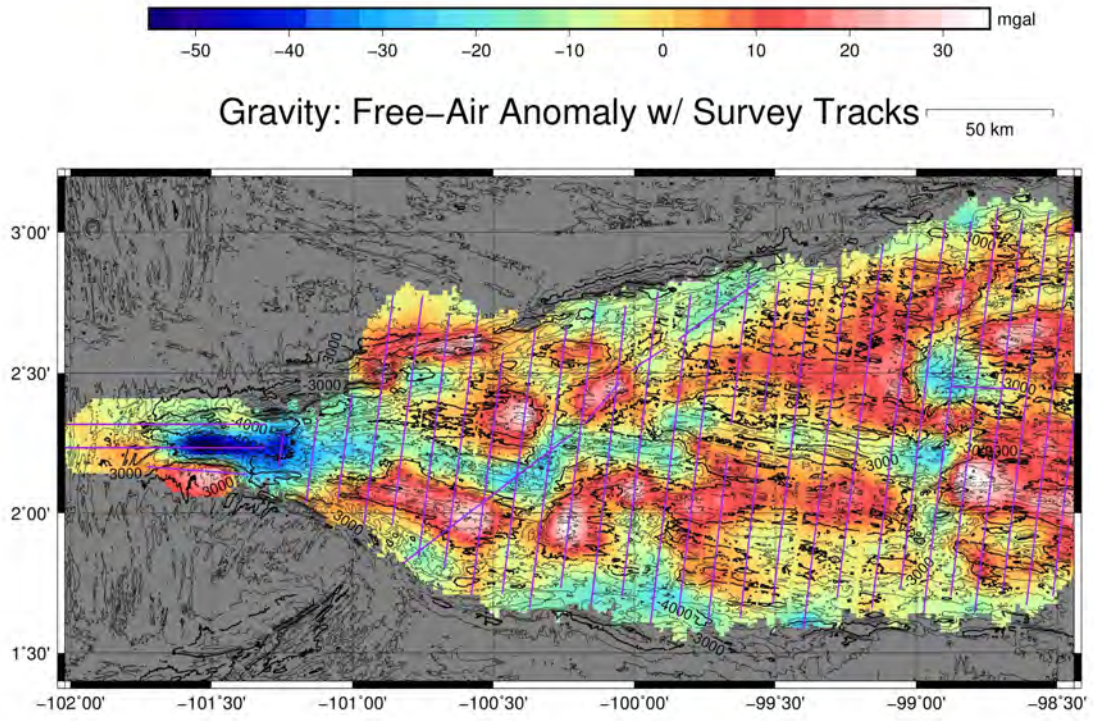

Fig 7. Free Air Anomaly (FAA)

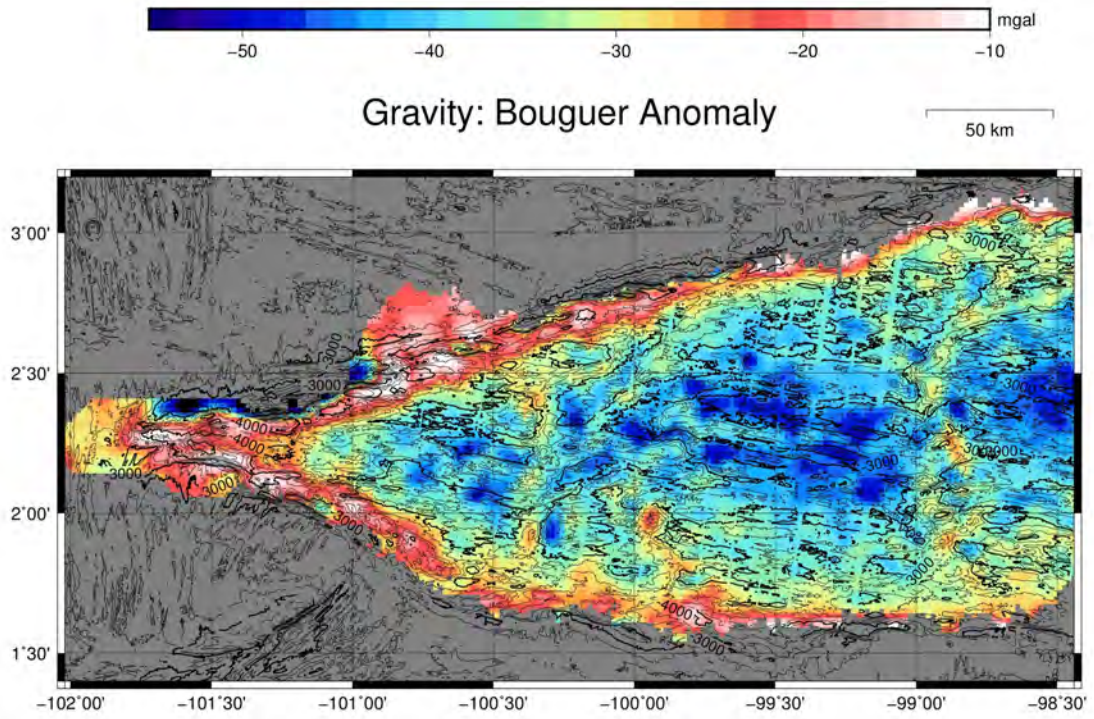

Figure 8. Bouguer Anomaly (BA) with sea-water density: 1.027 g/cc and oceanic crust density: 2.800 g/cc

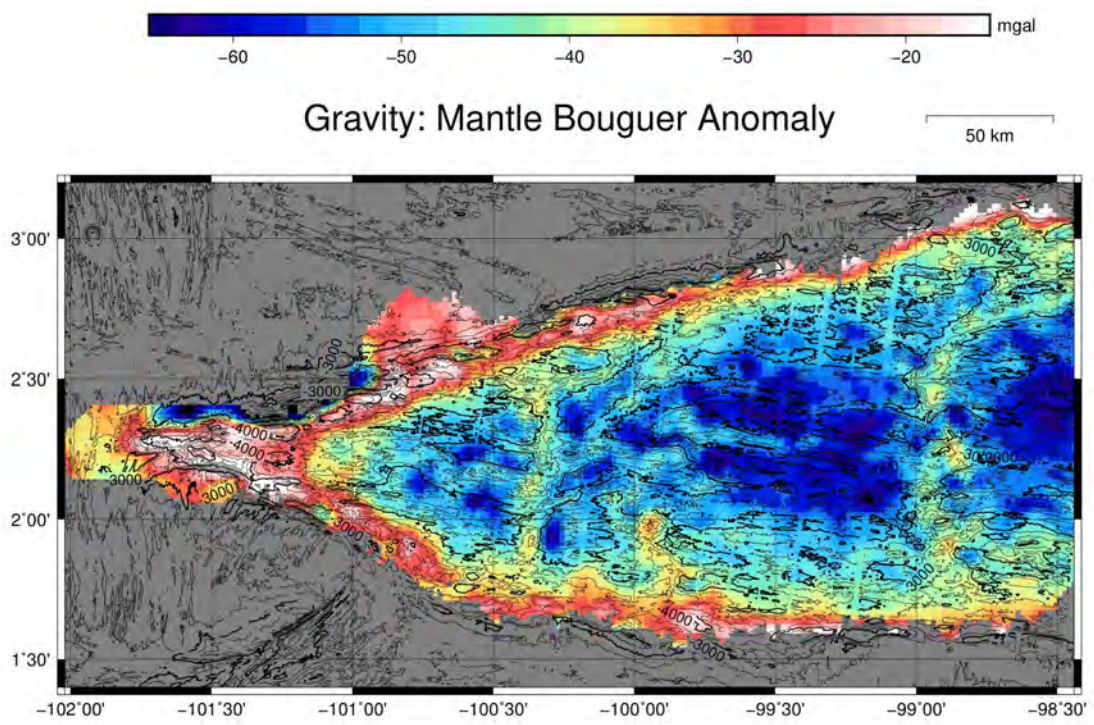

Figure 9. Mantle Bouguer Anomaly (MBA): 6 km below seabed

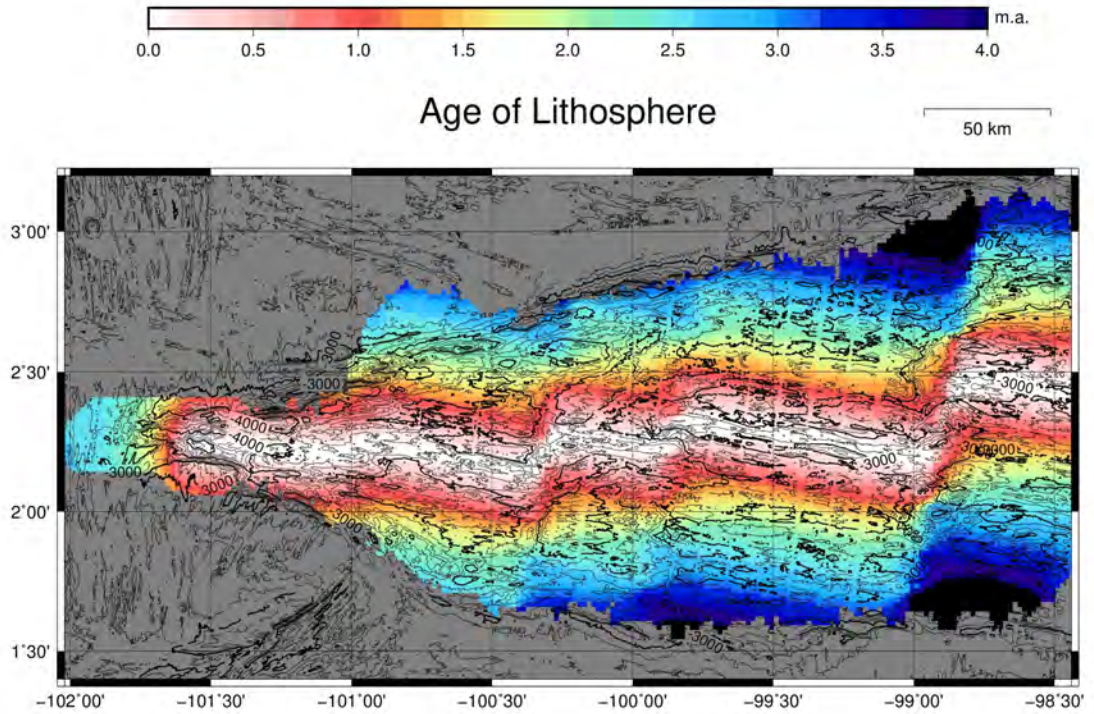

Figure 10. Age of Lithosphere: constructed by tracing the 'zero age' from the ridge axis and applying spreading rate of 40 km/m.a.

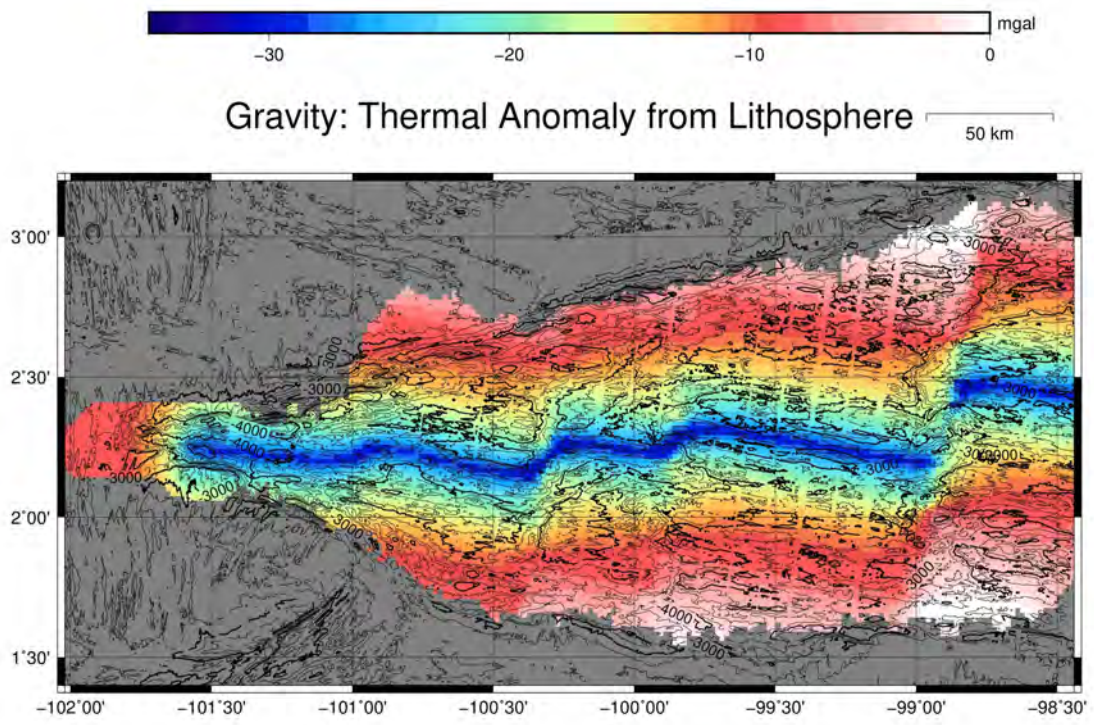

Figure 11. Thermal Anomaly: constructed using GDH1 plate model that 'flattens' at 95 km depth (Stein & Stein, 1992)

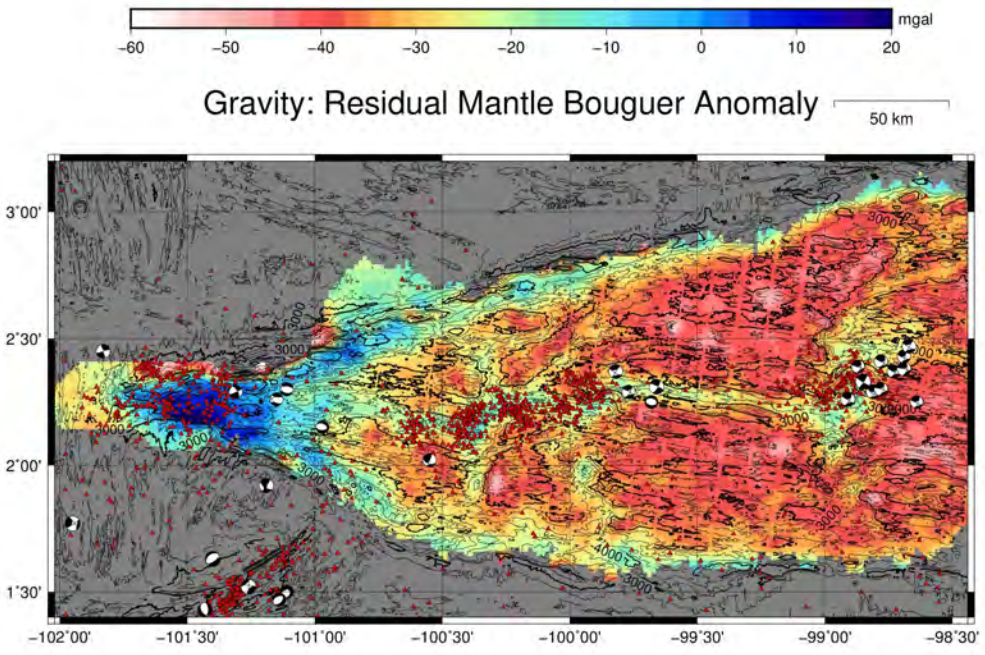

Figure 12. Residual Mantle Bouguer Anomaly (RMBA) with inverted colorbar, overlaid by seismicity and focal mechanism, showing the overal evolution from tectonic to magmatic crust

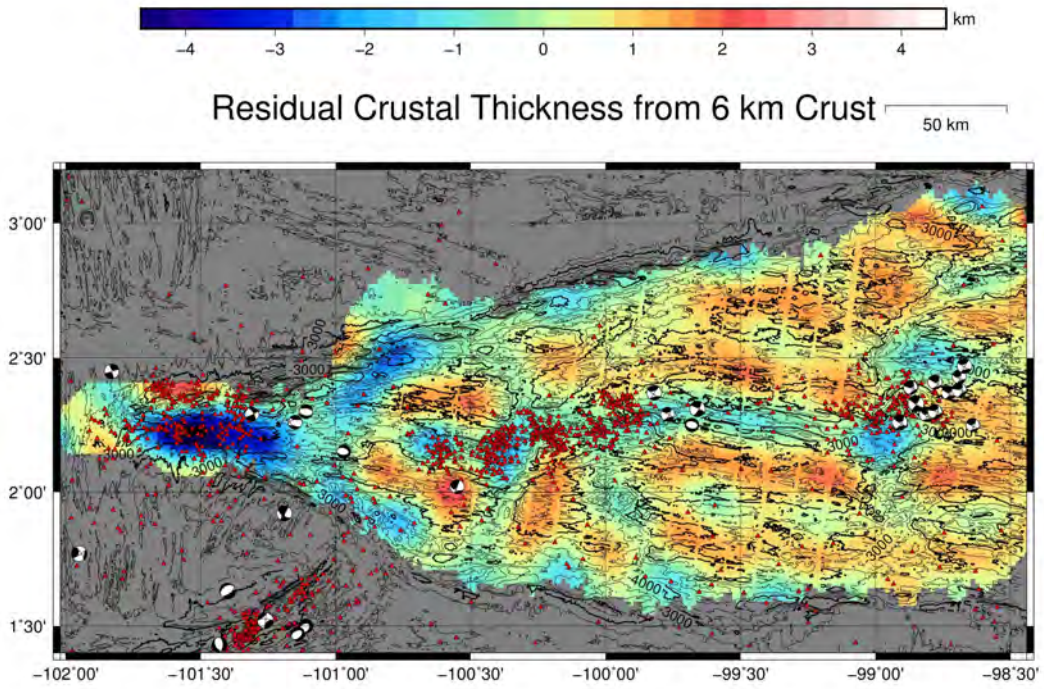

Figure 13. Residual Crustal Thickness (RCT): showing Hess Deep Crustal thickness being 1.5-3.0 km. Sensitivity test is still needed to optimize the cosine window that is key for computing RCT from RMBA. Earthquake locations are shown. Red symbols show hydroacoustically located events, Black and white symbols show teleseismically located events together with focal mechanisms.

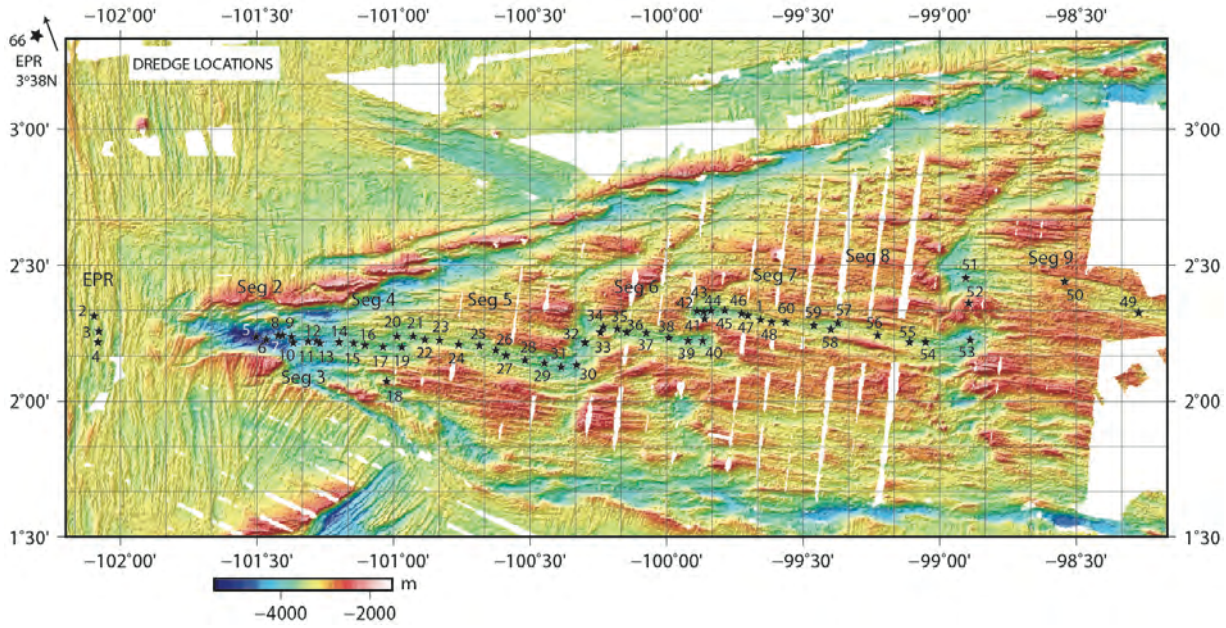

Figure 14. Dredge locations along the Cocos-Nazca Rift and East Pacific Rise.

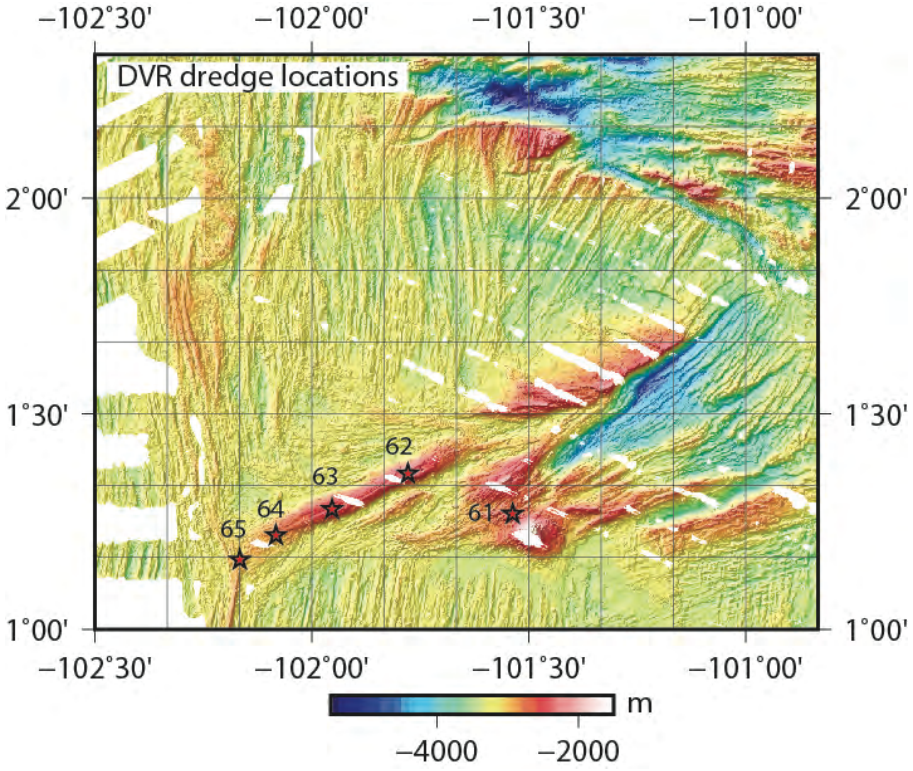

Figure 15. Dredge locations on and near the Dietz Volcanic Ridge.

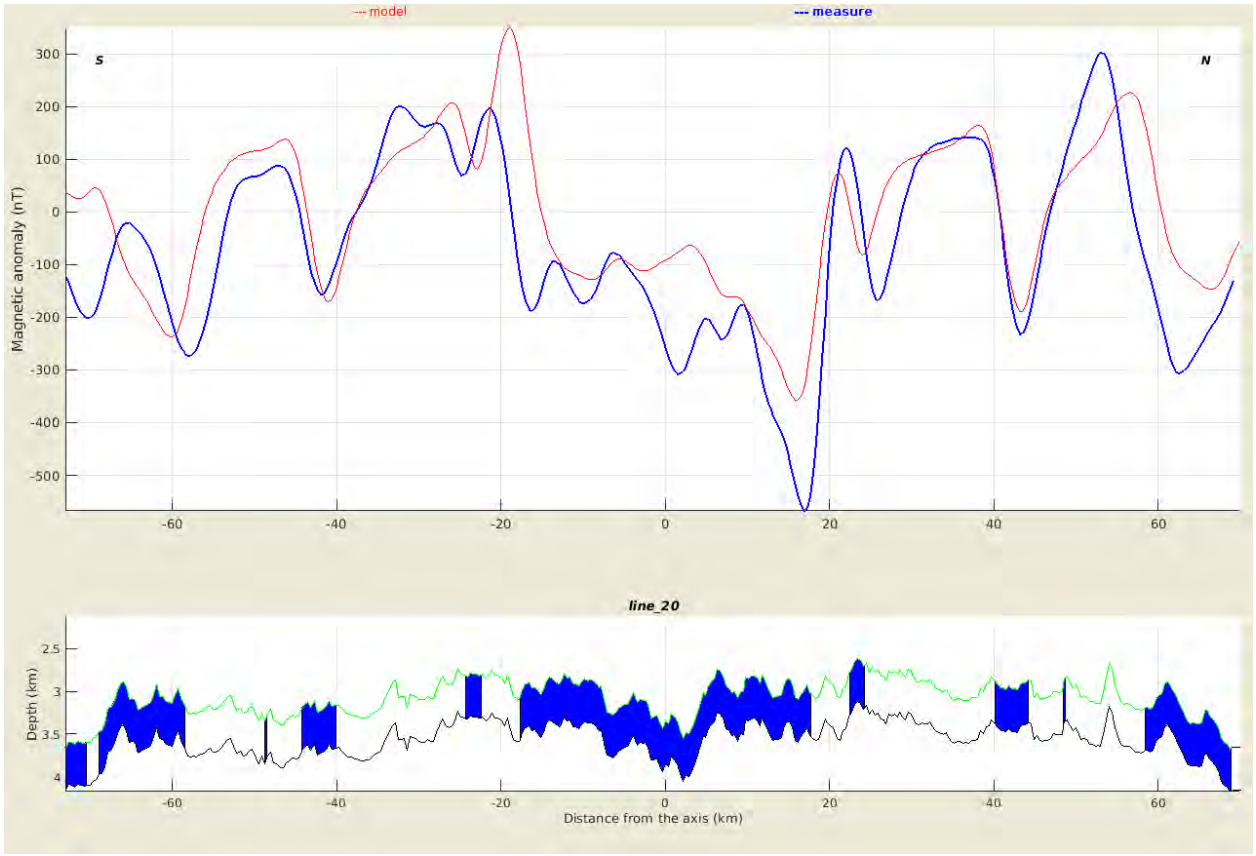

Figure 16: Modelling the magnetic anomaly profile for line 20 using the Modmag software (Mendel et al. 2005). Line 20 is within segment 8 and gives a simple nearly symmetric magnetic anomaly profile. A spreading rate of 45 km/Myr was used.

10. Tables excel files at: http://blogs.nicholas.duke.edu/cocosnazca/cruise-report/

Table 1. Dredge Location Log

Table 2. Sample Description Log (3 pages)

Dredge No.	No. Samples of type	Sample ID	IGSN ID	Notes to Scripps Repos.	Described by	Date	Glass? (Y or N)	Morph.	Dimensions (cm)	Shape/other comment	Textures A or P	Glass	Vesicularity %	Grain Size	Glassiness	Glass thickness (mm)	Glass quality	Alteration Degree	Mn Crust thickness (mm)	Alt Halo	Secondary Minerals	Total Phen%	Oliv%	Ave length	Max length	Plag%	Ave length	Max length	Cpx %	Ave length	Max length	Other %	Ave length	Max length	Comments	Hand Sample EK	Hand Sample DZ	Hand Sample IB	Thin Section Billets EK	Slabs for Chemistry EK	Glass EK
D01	6	-	SIO00000O	1 bag of small glass pieces		4/24/18																																			
		D01-1	SIO00000P		EMK	4/25/18	Y	P	13 x 8 x 8	foot shaped bud	P	GC	0	M	GR	8	F	F	0			5	1	1	1	99	3	5							Beautiful hand sample	X	X	X	x	X	X
		D01-2	SIO00000Q		BW	4/26/18	Y	P	7 x 4 x 4	toe	P	GC	< 1%	M	GR	4	F	F			Minor palagonite	5	5	1	1	95	3	5								X					X
		D01-3	SIO00000R		BW	4/26/18	Y	O	4 x 3 x 2	glass + diabase xenolith		GC	0	M	AG		F	F			Minor palagonite	10	5	1	1	95	3	7							Xenolith in glass						X
		D01-4	SIO00000S		BW	4/26/18	Y	O	7 x 4 x 3	nice flow banding		GC	< 1 %	M	AG		F	F			Minor palagonite	10	5	1	1	95	3	5													X
		D01-5	SIO00000T		EMK	4/26/18	Y	O	5 x 5 x 1	flat glass rind with striations		GC	0		AG		F	OS					1	1	1	99	4	6													
		D01-6	SIO00000U		DZ	4/26/18	Y	P	10 x 6 x 7	nice bud with large plag pheno	P	GC	0	M	GR	8	F	F				5	1	1	1	99	3	9							2 cm plag phenocryst	X					X
D02	4	-	SIO00000V	rest of dredge (4 buckets)																																					
		D02-1	SIO00000W		EMK	4/29/18	Y	P	11 x 10 x 12		P		2%	F	GR	3	PD	OS		10		1	50	1	1	50	1	1								X			X	X	X
		D02-2	SIO00000X		EMK	4/29/18	Y	P	16 x 13 x 12	pillow fragment	P		< 1 %		GV	2	VP	OS		2		1	10	1	1	90	1	1							Small amount of poor glass	X			X	X	X
		D02-3	SIO00000Y		EMK	4/29/18	Y	O	6 x 5 x 4	glass nodule		AG			AG		F					< 1				100	1	1													X
		D02-4	SIO00000Z		EMK	4/29/18	Y	O	4 x 3 x 3	glass nodule		AG			AG		F					< 1				100	1	1													X
D03	4	-	SIO00001A	Bag of station glass																																					
		D03-1	SIO00001B		IB	4/30/18	Y	O	4 to 6	glass bud fragment	A				AG		F	F																							X
		D03-2	SIO00001C		IB	4/30/18	Y	O	10 x 6 x 5		A	GC		F	AG		PD	OS				1	40	2	2	60	1	2													
		D03-3	SIO00001D		EMK	4/30/18		O	5 x 4 x 1	flat glass rind		GC			AG		PD	OS		3		3	20	1	2	80	1	1													
		D03-4	SIO00001E		IB	4/30/18	Y		4 x 2.5	glass chunk		GC		F	GC		P	OS				1	80	1	2	20	1	1													X
D04	5	-	SIO00001F	small bag of station glass																																					
		D04-1	SIO00001G		EMK	4/30/18	Y	O	4 x 3 x 1	glass rind	A	AG					F	OS		0															Minor OS						X
		D04-2	SIO00001H		EMK	4/30/18	Y	O	4 x 3 x 1	glass rind	A	AG			AG		F					1				100	<1	4							One large plagioclase						X
		D04-3	SIO00001I		EMK	4/30/18	Y	O	3 x 2.5 x 1	glass chunk	A	AG			AG		PD					< 1				100	<1	<1							with minor palagonite						X
		D04-4	SIO00001J		EMK	4/30/18	Y	O	2.5 x 2 x 1	glass rind		AG			AG		PD					1				100	< 2	2							with minor palagonite						X
		D04-5	SIO00001K		EMK	4/30/18	N	O	4 x 2 x 2	small whole rock chunk	P		0	F	NG			OS				3				100	< 1	2							only whole rock chunk in dredge,	X					
D05	5	-	SIO00001L	rest of dredge (4 buckets)																																					
		D05-1	SIO00001M		IB/CD	5/1/18	Y	P	Orig. 32 x 35 x 28	pillow with break out	P	GC	0	M	GR	5	P	OS				10				100	3	10								X				X	X
		D05-2	SIO00001N		EMK	5/1/18		P	10 x 14 x 10	pillow fragment oldish	P	GC	0	F	GV	2	PD, P	OS				1				100	1	3								X			X	X	X
		D05-3	SIO00001O		IB/CD	5/1/18	Y	P	5 x 9 x 4	nodular	P	GC	0	M	GV		PD	F				3				100	3	5							present in small quantities	X					X
		D05-4	SIO00001P		IB/CD	5/1/18	Y	P	6 x 6 x 5	nodular	P	GC	0	M	GV		F	F				3				100	3	4								X					X
		D05-5	SIO00001Q			5/1/18		P	4 x 4 x 4	nodular	P	GC	0	M	GV		P	OS				3	1	1	1	99	3	5								X					
D06	5	-	SIO00001R	rest of dredge (pillow fragments)																																					
		D06-1	SIO00001S		DZ/SA	5/1/18	Y	P	11 x 7 x 5	bud	A	GC	0		GR		P					1				100	2	3							Note that phenocrysts are in the	X			X		X
		D06-2	SIO00001T		DZ/SA	5/1/18	Y	P	x 5 x 4 and 6 x 6 x	sub spherical	P	GC	0	M	GV		PD	F				3				100	2.5	4								X			X		X
		D06-3	SIO00001U		DZ/SA	5/1/18	Y	P	14 x 13 x 9	irregular pillow end	P	GC	15%	M	GR	15	F, P	F			possibe in large ves	3	1	2	2	99	4	8								X					X
		D06-4	SIO00001V		DZ/SA	5/1/18	Y	O	5 x 2 x 1.5	glass finder		GC	0	F	AG		P	F				1				100	1	2													X
		D06-5	SIO00001W		DZ/SA	5/1/18	Y	O	5 x 2 x 2	oval		AG			AG		F	F				1				100	-	5							Less than 1 % plag phenos in glass						X
D07	5	-	SIO00001X	rest of dredge (rock + glass)																																					
		D07-1	SIO00001Y		BW	5/2/18	Y	P	17 x 12 x 9	glass pillow	P	GC	0	M	GR	5	F	OS				3				100	3	7								X					X
		D07-2	SIO00001Z		BW	5/2/18	Y	MF	15 x 13 x 5	drip features	P	GC	0	M	GR	3	PD, P	OS				1				100	3	7								X			X		
		D07-3	SIO00002A		BW	5/2/18	Y	O	4 x 3 x 3	glass nodule		GC	0	M	AG		F	F				1				100	2	2							Phenocrysts are in glass						X
		D07-4	SIO00002B		BW	5/2/18	Y	O	4 x 3 x 2	glass nodule		GC	0	M	AG		F	F				1				100	1	2							Phenocrysts are in glass						X
		D07-5	SIO00002C		BW	5/2/18	N	O	8 x 7 x 5	basaltic chunk	P		0	C	NG			OS				15				100	5	10								X					
D08	3	-	SIO00002D	rest of dredge (1 bucket)																																					
		D08-1	SIO00002E		IB	5/2/18	Y	P	8 x 7 x 7	toe shaped pillow	P	GC	0	M	GV			F				5				100	4	6								X					X
		D08-2	SIO00002F		CD	5/2/18	Y	P	10 x 8 x 8	pillow fragment	P	GC	0	M	GR	3	P	OS				1				100	3	5								X				X	X
		D08-3	SIO00002G		IB/CD	5/2/18	Y	P	19 x 22 x 26	big pillow	P	GC	0	M	GR	2	P	AH		10		3				100	2	2								X				X	X
D09	3	-	SIO00002H	vial of glass																																					
		D09-1	SIO00002I		CD	5/2/18	Y	O	3 x 5 x 2	glass chunk	P	GC		M	AG		OS					30				100	4	6							Phenocrysts are in glass						X
		D09-2	SIO00002J		EMK	5/2/18		O	3 x 2 x 1	glass chunk	P	GC	0		AG		P	OS				10				100	1	2							Minor palagonite						X
		D09-3	SIO00002K		CD	5/2/18	Y	O	2 x 2 x 1 ea.	small glass chunks	P	GC		M	AG		P	OS				15				100	2	5								X					
D10	2	-	SIO00002L					O																																	
		D10-1	SIO00002M		IB	5/2/18	Y	O	2 x 3 x 1	fragment	P	GC	0	M	AG		P	OS				1				100	1	2							Botriadal shape						X
		D10-2	SIO00002N	1 small bag glass pieces	CD	5/2/18	Y	O	1 x 1 x 1	fragment	P	GC	0	M	AG		P	OS				10				100	3	6													X
D11	3	-	SIO00002O	1 medium bag from main dredge																																					
		D11-1	SIO00002P		DZ/ SA	5/2/18	Y	P	13x11x6		P	GC	5	F	GR	10	P,PD	OS				5				100	1	3								X				X	X
		D11-2	SIO00002Q		DZ/ SA	5/2/18	Y	P	11x7x3	bud	P	GC	5	F	GR	8	F,P	F				3				100	1	1							Phenocrysts in glass and rock. Glass ans slabs and hand sample	X				X	X
		D11-3	SIO00002R		DZ/ SA	5/2/18	Y	P	8x7x6	bud	P	GC	5	M	GR	9	F,P	F				3				100	2	4							Phenocrysts in glass and rock. Glass and slabs and hand sample	X				X	X
D12	1	-	SIO00002S	small bag of glass																																					
		D12-1	SIO00002T	1 small bag	DZ	5/2/18	Y	O	4 x 4 1	glass chunks	P	GC	0	M	AG		F	F				1				100	2	3													X
D13	1	-	SIO00002U																																						
		D13-1	SIO00002V	small bag of glass	BW	5/3/18	Y	P	31 x 30 x 20	large glass pillow	P	GC	0	C	GR	6	P	F				10				100	5	10							Glass sent to Scripps. Large sample to Klein and Wernette	X					X
D14	5	-	SIO00002W	rest of dredge (3 buckets)																																					
		D14-1	SIO00002X		BW	5/3/18	Y	P	7 x 6 x 5	broken from larger pillow	A	AG	0		GV		F	OS																		X					
		D14-2	SIO00002Y		BW	5/3/18	Y	P	8 x 5 x 3	fractured pillow	A	AG	0		GV		F	F																		X					X
		D14-3	SIO00002Z		BW	5/3/18		MF	12 x 9 x 3	drip textures	A		0	F	NG			OS																		X					
		D14-4	SIO00003A		BW	5/3/18	Y	MF	7 x 4 x 3	glassy massive flow	A	AG	0		GR	5	F	F																		**X**					**X**
		D14-5	SIO00003B		BW	5/3/18	Y	O	4 x 4 x 2	glass nodule	A	AG	0		AG		F																								X
D15	6	-	SIO00003C	rest of dredge (3 buckets)																																					
		D15-1	SIO00003D		CD/IB	5/3/18	Y	P	35 x 26 x 28	big pillow block	P	GC	0	M	GR	2	PD	OS				3				100	3	6.00								X			X	X	X
		D15-2	SIO00003E		CD/IB	5/3/18	Y	P	27 x 15 x 6	flat pillow slab	P	GC	10	M	GR	3	F	F				10	1	1	1	99	4	10.00								X				X	X
		D15-3	SIO00003F		SA/DZ	5/3/18	Y	P	13 x 11 x 4	flat pillow fragment	P	GC	5	M	GR	5	F, P	F				5				100	4	8								X				X	X
		D15-4	SIO00003G		SA/DZ	5/3/18	Y	O	4 x 3 x 2	glass chunks	-	GC	0	M	AG		F	F								3	2	4								X					X
		D15-5	SIO00003H	Samples to Scripps	SA/DZ	5/3/18	N	P	30 x 21 x 14	medium pillow	P	GC	1	C	GR	6	F	OS				3	1	1	2	99	4	9							Samples to Scripps	X				X	X
		D15-6	SIO00003I		SA/DZ	5/3/18	Y	O	10 x 10 x 4	flat chunk, "bizzare"	P	GC	5	M	Stratbound		P	OS				3	1	1	1	99	3	6							"very bizzare piece of rock"	X				X	
D16	4	-	SIO00003J																																						
		D16-1	SIO00003K		DZ	5/3/18	Y	P	7 x 5 x 4	bud	A	AG	0		AG		F	F																		X					X
		D16-2	SIO00003L		DZ	5/3/18	Y	P	5 x 4 x 4	small bud	P	GC	0	M	AG		F	F				< 1				100	1	3								X					X
		D16-3	SIO00003M	Sample to Scripps	DZ	5/3/18	Y	P	12 x 8 x 6	fresh glass with cryst core	P	GC	3	M	GR	10	F	OS				1				100	1	3								X				X	X
		D16-4	SIO00003N		DZ/SA	5/3/18	Y	P	5.5 x 4 x 3	irregular pillow fragment	P	GC	0	M	GR	10	F,P	OS				10	1	1	2	96	1	2	3	1	2					X					X
D17	4	-	SIO00003O	glass vial and bag																																					
		D17-1	SIO00003P	Sample to Scripps	DZ/SA	5/3/18	Y	P	16 x 11 x 9	med-large truncated pillow	A	GC	1		GR	3	F,p	OS																		X				X	X
		D17-2	SIO00003Q		DZ/SA	5/3/18	Y	P	10 x 6 x 5	small pillow	P	GC	1	F	GR	9	F	F				1				100	1	1							Black coating on glass	X					X
		D17-3	SIO00003R		DZ/SA	5/3/18	Y	P	8 x 6 x 4	irregular thick glass rind	P	GC	1	M	GR	12	F	F				1				100	3	7							Black coating on glass	X					X
		D17-4	SIO00003S		DZ/SA	5/3/18	Y		12 x 7 x 6	irregular	P	GC	0	M	GR	3	F,p	OS				10				100	1	4								X				X	X
D18	4	-	SIO00003T	rest of dredge (2 buckets)																																					
		D18-1	SIO00003U		BW	5/4/18	N	O	4 x 2 x 1	breccia	P			M	GR	5		OS				5														X					
		D18-2	SIO00003V		BW	5/4/18	N	O	1.5 x 1 x1	basalt with crust	P			F					3mm			10													interior is porphyritic, illustration on	X					
		D18-3	SIO00003W		BW	5/4/18	N	O	2.5 x 1 x 0.5	clay-rich breccia with crust									3mm		clay														illustration on log sheet	X					
		D18-4	SIO00003X		BW	5/4/18	N	O	2 x 1 x 1	possible serp. Breccia								OS			clay														illustration on log sheet	X					
		D18-5	SIO00003Y		BW	5/4/18	N	O	see comments	basalt rubble				F				OS	Y																to look at carefully. Smallest 1 x 1 x1. medium 3 x 5 x 2						
D19	4	-	SIO00003Z	rest of dredge (1 bucket)																																					
		D19-1	SIO00004A		BW	5/4/18	Y	P	20 x 20 x 20		A	AG			GV		PD	OS, EA			clay														minimal glass. Altered piece dimensions of 20 x 20 x 20.	X					
		D19-2	SIO00004B		BW	5/4/18	N	O	6 x 5 x 5	massive basalt chunk	A				NG			OS																		X					
		D19-3	SIO00004C		BW	5/4/18	Y	O	4.5 x 3.5 x 2	ropey flow	A				GV		F	F																	minimal glass	X					
		D19-4	SIO00004D		BW	5/4/18	Y	SG	2 x 2 x 1	statiion glass	A	AG			AG		F, PD, P																		dimensions for largest piece, some of each type of glass (alteration)						X
D20	2	-	SIO00004E	rest of dredge (1 bucket)																																					
		D20-1	SIO00004F	yes	CD	5/4/18	Y	P	10 x 10 x7	nodule	P	GC	1	F	GV		P	OS				1				50			50							X				X	X
		D20-2	SIO00004G		CD	5/4/18	Y	P	10 x 7 x 7	nodule	P		0	F	GV		P	OS				1				50			50							X					
		D20-3	SIO00004H	yes	C/IB	5/4/18	Y	P	40 x 50 x 40	large pillow	P		5	M	GR	5	P	OS				10				100	3	10								X			X	X	X
D21		-	SIO00004I	bag of samples																																					
		D21-1	SIO00004J		DZ/SA	5/4/18	Y	O	4.5 x 3 x 2	irregular chunks with sharp edges	P	GC	0	M	AG		F,P	F				3	1	2	2	99	3	5													X
		D21-2	SIO00004K		DZ/SA	5/4/18	Y	O	3.5 x 3 x 2	irregular	P	GC	0	M	AG		F,P	F				3	1	1	1	99	2	3													X
		D21-3	SIO00004L		DZ/SA	5/4/18	Y	O	3 x 3 x 3	irregular	P	GC	0	M	AG		F,P	F				3	1	2	2	99	4	7													X
		D21-4	SIO00004M		DZ/SA	5/4/18	Y	O	3 x 2.5 x 1.5	irregular	P	GC	0	M	AG		F,P	F				1	1	1	1	99	3	7													X
		D21-5	SIO00004N		DZ/SA	5/4/18	Y	P	15 x 7 x 8	bud	P	GC	1	M	GR	4	F	F				5	2	1	3	98	4	10								X				X	X
		D21-6	SIO00004O	yes	DZ/SA	5/4/18	Y	P	15 x 11 x 11	pillow fragment	P	GC	0	M	GR	5	F,P	OS				5	2	1	2	98	3	6								X				X	X
D22		-	SIO00004P	rock fragment																																					
		D22-1	SIO00004Q		SA/DZ	5/4/18	Y	P	13 x 10 x 6	slab	P	GC	1	M	GR	8	F,P	OS				20	1	2	3	99	4	8								X				X	X
		D22-2	SIO00004R		SA/DZ	5/4/18	Y	P	8 x 6 x 5	small fragment of pillow	P	GC	1	M	GR	7	F,P	OS				20		4	4		4	12												X	X
		D22-3	SIO00004S		SA/DZ	5/4/18	Y	P	8 x 5 x 4	end of small pud	P	GC		M	GR	4	F					5	1	1	1	99	4	11								X					X

							Sample characteristics			Textures							Alteration					Mineralogy												Sample Distribution											
Dredge No.	No. Samples of type	Sample ID	IGSN ID	Notes to Scripps Repos.	Described by	Date	Glass? (Y or N)	Morph.	Dimensions	Shape/other comment	A or P	Glass	Vesicularity	Grain Size	Glassiness	Glass	Glass	Degree	Mn Crust	Alt	Secondary Minerals	Total	Oliv%	Ave	Max	Plag%	Ave	Max	Cpx %	Ave	Max	Other %	Ave	Max	Comments	Hand Sample				Thin Section Billets			Slabs for Chemistry			Glass		
									(cm)				%			thickness (mm)	quality		thickness (mm)	Halo		Phen%		length	length		length	length		length	length		length	length		EK	DZ	IB		EK			EK			EK		
D23		-	SIO00004T	rest of dredge (1 bucket) +D23-3																																													
		D23-1	SIO00004U		BW	5/5/18	Y	P	32 x 28 x 22		P	GC		M	GV		PD,P	OS				1					100	3	5																				X		
		D23-2	SIO00004V		BW/SC	5/5/18	Y	P	17 x 12 x 10	oxidized	A	GC			GR	5		OS																				X										X		
		D23-3	SIO00004W	yes	BW	5/5/18	Y	O	5 x 3 x 2		P	AG		M	GV		PD,P	OS			clay	1			100	3	5							X													
		D23-4	SIO00004X	yes	BW	5/5/18	Y	O				AG					PD,P																													X		
D24		-	SIO00004Y	rest of dredge (2 buckets)																																													
		D24-1	SIO00004Z		GA	5/5/18	N	P	10 x 9 x 7		A				NG			OS																			X													
		D24-2	SIO00005A		BW/GA	5/5/18	Y	P	16 x 16 x 12	fragment	A	GC	1	A	GR	5	PD,P	OS			clay																X										X		
		D24-3	SIO00005B		GA	5/5/18		SF	10 x 8 x 8	ropey flow	P			M	GR	5	PD,P	OS				2															X													
		D24-4	SIO00005C		BW	5/5/18	N	O	Assorted < 3 cm	basaltic rubble	A							OS,EA			clay																X													
D25		-	SIO00005D	rest of dredge (4 buckets)																																													
		D25-1	SIO00005E		BW	5/5/18	Y	P	12 x 8 x 6		P	GC	< 1	M	GR	7	F,P	F				1					100	1	7							X										X		
		D25-2	SIO00005F		BW	5/5/18	Y	P	10 x 9 x 7		P	GC	1	F	GV		PD	OS			clay																X													
		D25-3	SIO00005G		BW	5/5/18	Y	P	9 x 9 x 3	basaltic chunk	P		1	F	GR	4	F	F				1					100	1	1							X										X		
D26		-	SIO00005H	rest of dredge (3 buckets)																																													
		D26-1	SIO00005I		CD/IB	5/5/18	Y	P	10 x 5 x 6	fragment with globule	P	GC		F	GV		PD	OS				3					100	2	4							X										X		
		D26-2	SIO00005J		CD/IB	5/5/18	Y	P	14 x 4 x 3	thin pillow fragment	P	GC	0	M	Gr	7	P	F				5	10	1	5	90	2	4							X				X			X			X		
		D26-3	SIO00005K		CD/IB	5/5/18	Y	P	13 x 7 x 9	pillow fragment	P	GC		M	GV		P	OS				3					100	2	5							X				X			X			X		
		D26-4	SIO00005L		CD/IB	5/5/18	Y	P	6 x 10 x 5	pillow fragment	P	GC		M	GV		F	F				3					100	3	5							X													
D27		-	SIO00005M	rest of dredge + station glass (2 buckets)																																													
		D27-1	SIO00005N		SA/DZ	5/5/18	Y	P	7 x 5 x 4	small bud	P	GC		M	GR	12	F	F				10					100	2	3							X										X		
		D27-2	SIO00005O		SA/DZ	5/5/18	Y	P	18 x 12 x 12	fragment of big pillow	P	GC		M	GR	9	F,P	OS				10	1	1	2	99	1	3							X							X			X		
		D27-3	SIO00005P		SA/DZ	5/5/18	Y	O	3.5 x 2.5 x 2	chunk	P	GC		M	AG		F,P	F				5	1	1	1	99	1	3																	X		
		D27-4	SIO00005Q		SA/DZ	5/5/18	Y	O	3 x 3 x 2	chunk	P	GC		M	AG		F,P	F				5	1	1	1	99	2	4																	X		
		D27-5	SIO00005R		SA/DZ	5/5/18	Y	O	6 x 3 x 1	chunk	P	GC	0	M	AG		F,P	F				10					100	2	3																	X		
		D27-6	SIO00005S		SA/DZ	5/5/18	Y	O	4 x 3.5 x 1	chunk	P	GC	0	M	AG		F,P	F				10					100	1	3																	X		
		D27-7	SIO00005T		SA/DZ	5/5/18	N	O	12 x 12 x 8	irregular rope structure	P		10	M	NG			OS				10	1	1	1	99	2	5														X			X		
		D27-8	SIO00005U		SA/DZ	5/5/18	N	O	12 x 6 x 5	drum stick old rock	P			M	NG			OS				15	1	1	1	99	1	3							in special sample bucket	X													
D28		-	SIO00005V	None sent. Dredge << 1/4 lb																																													
		D28-1	SIO00005W		DZ	5/5/18	Y	O	2 x 1 x 1	crumbs	P			M	AG		F	F				3					100	1	2																	X		
D29		-	SIO00005X	None sent. Dredge approx. 1/2 lb																																													
		D29-1	SIO00005Y		BW	5/6/18	N	O	6.5 x 5.5 x 2	basalt fragment	P			M	NG			F				5	5	2	2	90	2	4	5	3	3				X													
		D29-2	SIO00005Z		BW	5/6/18	Y	O	5 x 3 x 1	glass chunk		GC		M	AG		P					1					100	1	1																	X		
		D29-3	SIO00006A		BW	5/6/18	Y	O	3 x 2 x 1	glass chunk		GC		M	AG		mP	F				1					100	1	1																	X		
		D29-station glas	SIO00006B		BW	5/6/18	Y																																							X		
D30		-	SIO00006C	rest of dredge (2 buckets)																																													
		D30-1	SIO00006D		CD/IB	5/6/18	Y	O	4 x 3 x 3	small glass bud	A	AG			AG		F	F																														X		
		D30-2	SIO00006E		CD/IB	5/6/18	Y	O	7 x 4 x 6	glass fragment	A	AG			AG		P	OS																														X		
		D30-3	SIO00006F		CD/IB	5/6/18	Y	P	13 x 10 x 9	pillow fragment	P	GC		F	GR	4	P	OS				1	10	2	2	90	1	2							X				X			X			X		
D31		-	SIO00006G	rest of dredge																																													
		D31-1	SIO00006H		BW	5/6/18	Y	O	4 x 3 x 3	glass chunk		GC		M	AG		F,P					1					100	1	4																	X		
		D31-2	SIO00006I		BW	5/6/18	Y	O	3.5 x 3 x 2	glass chunk		GC		M	AG		PD,P				clay	1					100	1	2																	X		
		D31-3	SIO00006J		BW	5/6/18	Y	MF	11 x 6 x 4	heavy oxidation	P	GC		M	GR	7	PD,P	OS			clay	1					100	1	3							X										X		
D32		-	SIO00006K																																														
		D32-1	SIO00006L		CD/IB	5/6/18	Y	O	5 x 4 x 3	glass tube	P	GC			AG		P	F				< 1					100	1	2																	X		
		D32-2	SIO00006M		CD/IB	5/6/18	Y	O	6 x 4 x 6	glass bud	P	GC		F	GR	10	F	F				1					100	1	1							X										X		
		D32-3	SIO00006N		CD/IB	5/6/18	Y	P	5 x 4 x 3	small pillow w/ glass	P	GC		F	GR	4	F					1					100	1	1							X													
		D32-4 (station gla	SIO00006O	yes	CD/IB	5/6/18	Y	O		glass fragments																																			?		
D33		-	SIO00007V	None sent. Small dredge																																													
D34		-	SIO00006P	rest of dredge																																													
		D34-1	SIO00006Q	yes	BW	5/7/18	N	O	7 x 5 x 2	basalt fragment	P			med-coarse				OS		5		10	40	3	7	60	3	7							X							X					
		D34-2	SIO00006R		BW	5/7/18	N	O	6 x 4 x 2	basalt fragment	P			med-coarse				OS				10	40	3	5	60	3	10							X										?		
		D34-3	SIO00006S	yes	BW	5/7/18	N	O	8 x 7 x 5	ol in plag phenocryst (basalt)	P			med-coarse				OS			clay	12.5	30	3	5	70	5	15							X													
		D34-4	SIO00006T		BW	5/7/18	Y	O	5 x 3 x 3	glass chunk		GC		M	AG		PD,P	OS				15					100	3	5																	X		
		D34-5	SIO00006U		BW	5/7/18	Y	O	4 x 2 x 2	glass chunk		GC		M	AG		PD,P	OS				20					100	3	5																	X		
D35		-	SIO00006V																																														
		D35-1	SIO00006W	yes	BW	5/7/18	Y	O	10 x 10 x 10	A' a' or hyaloclastite							PD	OS			aglutenated 60% glass?																X										X		
		D35-2	SIO00006X		BW	5/7/18	Y	O	9 x 9 x 5	A' a' or hyaloclastite							PD	OS			aglutenated 60% glass?																X										X		
D36		-	SIO00006Y	rest of dredge (1 bucket)																																													
		D36-1	SIO00006Z	yes	BW	5/7/18	Y	P	17 x 11 x 8		P	GC		M	GR	5	F	OS				5	20	1	2	80	1	5							X							X			X		
		D36-2	SIO00007A		BW	5/7/18	N	O	12 x 7 x 3	fragment	P			med-coars	NG			OS,EA				5	30	1	4	70	1	10							X													
		D36-3	SIO00007B		BW	5/7/18	Y	O	5 x 4 x 3	glass chunk		GC		M	AG		F	F				5					100	1	2																	X		
		D36-4	SIO00007C		BW	5/7/18	Y	O	2 x 2 x 2	glass chunk		GC		M	AG		F	F				5					100	1	2																	X		
		D36-5	SIO00007D	yes	BW	5/7/18	Y	P	46 x 30 x 30	big pillow glassy rind	P	GC		med-coars	GR	5	F	OS			clay	5	5	1.5	3	95	2	7							X										X		
D37		-	SIO00007E	station glass																																													
		D37-1	SIO00007F	yes	IB/CD	5/7/18	Y	P	11 x 8 x 4	thin pillow fragment	P	GC		M	GR	6	P	OS				3					100	3	6							X										X		
		D37-2	SIO00007G	yes	IB/CD	5/7/18	Y	P	8 x 4 x 3	pillow fragment	P	GC		M	GR	10	P	OS				3					100	3	4							X										X		
		D37-3	SIO00007H	yes	IB/CD	5/7/18	Y	P	8 x 5 x 3	pillow fragment	P	GC		M	GV		F					1					100	4	6							X													
D38		-	SIO00007I	rest of dredge (2 buckets)																																													
		D38-1	SIO00007J	yes	DZ/SA	5/7/18	Y	O	13 x 8 x 5		P	GC	1	M	GR	8	F	F				10	1	1	2	99	3	6							X							X			X		
		D38-2	SIO00007K		DZ/SA	5/7/18	Y	O	3 x 2 x 1.5	glass chunk or nodule	P	GC		M	AG		F	F				5					100	2	4																	X		
		D38-3	SIO00007L		DZ	5/7/18	Y	O	3.5 x 2 x 1	chunk	P	GC		M	AG		F					5					100	1	3																	X		
		D38-4	SIO00007M		SA	5/7/18	Y	O	5 x 3.5 x 3	rounded chunk	P	GC		M	AG		F,P		thin			10	1	1	1	99	2	4																	X		
		D38-5	SIO00007N		DZ/SA	5/7/18	Y	O	3.5 x 3 x 1	chunk	P	GC		M	AG		P	OS				7					100	1	7																	X		
		D38-6	SIO00007O		DZ/SA	5/7/18	Y	O	4.5 x 2.5 x 1	chunk	P	GC		M	AG		P	OS				7					100	1	3																	X		
		D38-7	SIO00007P	yes	DZ/SA	5/7/18	Y	P	15 x 7 x 8	fragment of pillow	P	GC		M	GR	15	P	OS	thin			10	1	1	1	99	2	4							X							X			X		
		D38-8	SIO00007Q	yes	DZ/SA	5/7/18	Y	P	31 x 27 x 25		P	GC		M	GR	12			thin			5	1	1	1	99	2	4							X							X			X		
D39		-	SIO00007R	None sent. Small dredge																																													
		D39-1	SIO00007S		DZ	5/7/18	Y	O	4 x 3 x 2	chunk	P	GC		M	GV		F,P	F				10					100	2	4																	X		
D40		-	SIO00007T	None sent. Small dredge																																													
		D40-station glas	SIO00007U		DZ	5/7/18	Y			small glass fragments		GC			AG		F	F									100	1	1																	X		
D41		-	SIO00007W	rest of dredge																																													
		D41-1	SIO00007X		CD/IB	5/8/18	N	P	8 x 5 x 5	basalt fragment	P	AC		M	NG			OS				20	5	2	2	95	3	5							X							X					
		D41-2	SIO00007Y		IB/CD	5/8/18	N	P	7 x 2 x 3	fragments	P	AC		M	NG			OS			chlorite veins and ma	1				99	2	4	1	1	1				X													
		D41-3	SIO00007Z		IB/CD	5/8/18	N	P	9 x 5 x 5		P	AC		M	NG			OS			chlorite margins	1				100	2	4							X													
D42		-	SIO00008A	rest of dredge																																													
		D42-1	SIO00008B		IB/CD	5/8/18	Y	P	12 x 5 x 6	pillow fragments	P	GC		F	GV		P	OS				3	1	1	1	99	1	3							X				X			X			X		
D43		-	SIO00008C																																														
D44		-	SIO00008D																																														
		D44-1	SIO00008E	yes	CD	5/8/18	Y	O	8 x 7 x 1	glass rind	P	GC		M	AG			OS				35					100	2	5														X					
		D44-2	SIO00008F	yes	CD	5/8/18	Y	O	9 x 2 x 1	glass	P	GC		M	AG		P	OS				20	10	3	3	90	2	5																	X		
		D44 (station glas	SIO00008G		CD	5/8/18	Y	O		station glass																																					
D45		-	SIO00008H																																														
		D45-1	SIO00008I		CD	5/8/18	Y	O	5 x 3 x 1	all glass	P	GC		M	AG		F,P	F				5	1	1	1	99	2	5																	X		
		D45-2 (station gla	SIO00008J		IB/CD	5/8/18	Y	O		station glass																																					
D46		-	SIO00008K	rest of dredge																																													
		D46-1	SIO00008L	yes	SA/DZ	5/8/18	Y	O	14 x 13 x 5	glass septa	P	AG		F	GR	4	F,P	OS				5					100	1	2							X							X			X		
		D46-2	SIO00008M		SA/DZ	5/8/18	Y	P	13 x 10 x 7	wrinkly glass rind	P	GC		F	GR	3	F	F	thin film			1					100	1	3							X							X			X		
		D46-3	SIO00008N		SA/DZ	5/8/18	Y	P	7 x 4 x 5	nodular	P				GR	3	F					5					100	1	1							X										X		
		D46-4	SIO00008O		SA/DZ	5/8/18	Y	O	7 x 3 x 3	glass septa		AG			AG		F																														X		
		D46-5 (station gla	SIO00008P		SA/DZ	5/8/18	Y		2 x 1.5 x .5																																			X		
		D46-6 (station gla	SIO00008Q		SA//DZ	5/8/18	Y		2 x 1 x 1																																			X		
D47		-	SIO00008R	rest of dredge																																													
		D47-1	SIO00008S		IB/SA	5/9/18	Y	O	14 x 7 x 8		P	GC			GR	5	F	OS				2	10	1	1	90	2	4							X							X			X		
		D47-2	SIO00008T		IB/SA	5/9/18	Y	P	11 x 5.5 x 7	pillow chunk	P	GC		M	GV		F	F				2					100	3	5							X							X			X		
		D47-3	SIO00008U		IB/SA	5/9/18	Y	P	8.5 x 5 x 6	pillow fragment	P	GC		M	GR	3	P	OS				5					100	2	4							X							X			X		
		D47-4	SIO00008V		IB/SA	5/9/18	Y	P	5 x 5 x 3	bud fragment	P	GC	1	M	GV		F	F				3					100	2	4							X										X		
		D47-5	SIO00008W		IB/SA	5/9/18	Y	P	5.5 x 3.5 x 4		P	GC		M	GR	6	P	OS				1					100	1	2							X										X		
		D47-6	SIO00008X		IB/SA	5/9/18	Y	O	6.5 x 5 x 1		P	GC		M	AG		P	OS				3					100	3	5																	X		
D48		-	SIO00008Y	rest of dredge																																													
		D48-1	SIO00008Z	yes	DZ	5/9/18	Y	P	16 x 11 x 7		P	GC		M	GR	12	F	F				20	1	1	1	99	3	10							X							X			X		
		D48-2	SIO00009A		DZ	5/9/18	Y	P	9 x 7 x 6		P	GC		M	GR	10	F	F,OS				20					100	3	7							X										X		
		D48-3	SIO00009B		DZ	5/9/18	Y	O	8 x 5 x 5	bud	P	GC		M	GR	10	F,P	F				20	1	1	1	99	3	7							X										X		
		D48-4	SIO00009C		DZ	5/9/18	Y	O	5 x 4 x 3	bud	P	GC		M	AG		F,P	F				20					100	2	4																	X		
		D48-5	SIO00009D		DZ	5/9/18	Y	O	4.5 x 3 x 1.5	fragment of bud	P	GC		M	AG		F,P	F				20					100	3	7																	X		

									Sample characteristics		Textures							Alteration					Mineralogy													Sample Distribution												
Dredge No.	No. Samples of type	Sample ID	IGSN ID	Notes to Scripps Repos.	Described by	Date	Glass? (Y or N)	Morph.	Dimensions	Shape/other comment	A or P	Glass	Vesicularity	Grain Size	Glassiness	Glass	Glass	Degree	Mn Crust	Alt	Secondary Minerals	Total	Oliv%	Ave	Max	Plag%	Ave	Max	Cpx %	Ave	Max	Other %	Ave	Max	Comments	Hand Sample				Thin Section Billets			Slabs for Chemistry			Glass		
									(cm)				%			thickness (mm)	quality		thickness (mm)	Halo		Phen%		length	length		length	length		length	length		length	length		EK	DZ	IB		EK			EK			EK		
		D48-6	SIO00009E		DZ	5/9/18	Y	O	4 x 3 x .5	chunk	P	GC		M	AG		F,P					20				100	3	7																		X		
		D48-7	SIO00009F		DZ	5/9/18	Y	O	4 x 2.5 x 1	chunk	P	GC		M	AG		F,P					20	1	1	1	99	1	3																		X		
D49		-	SIO00009G	rest of dredge																																												
		D49-1	SIO00009H		CD/IB	5/13/18	Y	P	4 x 3 x 2	pillow fragment	P	GC	0	M	GR	8	P	F				5	1	1	1	99	2	6								X				X			X			X		
		D49-2	SIO00009I	yes	CD/IB	5/13/18	Y	P	10 x 4 x 3	pillow bud	P	GC	0	M	GR	5	P	OS				5				100	3	6								X												
		D49-3	SIO00009J	yes	CD/IB	5/13/18	Y	P	5 x 5 x 4	pillow fragment	P	GC	1	M	GR	3	P	OS				10	5	1	2	95	3	5								X							X			X		
D50		-	SIO00009K	rest of dredge + station glass																																												
		D50-1	SIO00009L		SA//DZ	5/13/18	Y	P	10 x 10 x 9	irregular	P	GC	3	F	GR	13	P, VP	OS				20				100	1	1								X							X			X		
		D50-2	SIO00009M		SA//DZ	5/13/18	Y	O	11 x 7 x 4	irregular (fingers looking)	A	GC	0		GR	8	F,P																			X												
		D50-3	SIO00009N		SA//DZ	5/13/18	Y	P	12 x 7 x 7	bud, pillow fragment	P	GC	<3	F	GR	5	F,P					20				100	1	1								X							X			X		
D51		-	SIO00009O	rest of dredge																																												
		D51-1	SIO00009P		SA//DZ	5/13/18	Y	P	12 x 12 x 10		P	GC	3	M	GV		F,P	OS	hin coating			20	1	1	2	99	1	4								X							X			X		
		D51-2 (station gla	SIO00009Q	yes	SA//DZ	5/13/18	Y	O	6 x 4 x 1,5	chunk		GC		F	AG		F,P					10				100	1	2																		X		
		D51-3 (station gla	SIO00009R		SA//DZ	5/13/18	Y	O	3,5 x 4 x 1	chunk		GC		F	AG		F,P					10				100	1	1																		X		
D52		-	SIO00009S	None sent.																															Empty dredge. Small amount of													
D53		-	SIO00009T	None sent.																																												
		D53-1	SIO00009U		BW	5/14/18	Y	O	5 x 3 x 0,5	larger glass rind		AG			AG		P					20				100	2	5																		X		
		D53-2	SIO00009V		BW	5/14/18	Y	O	2 x 2 x 0,5	small glass chunk		AG			AG		P																													X		
		D53-3	SIO00009W		BW	5/14/18	N	O	6 x 4 x 3	altered fragment with large vesicules	A	NG			NG			OS																		X												
D54		-	SIO00009X	rest of dredge (2 buckets)																																												
		D54-1	SIO00009Y		BW	5/14/18	Y	P	11 x 9 x 8		P	GC		M	GR	8	F	OS				5				100	1	5								X							X			X		
		D54-2	SIO00009Z		BW	5/14/18	Y	SF	11 x 8 x 4		P	GC		M	GR	8	F,PD	OS				1				100	2	5								X										X		
		D54-3	SIO0000A0		BW	5/14/18	Y	O	3 x 2 x 2	glass chunk		GC			AG		F					5				100	1	5																		X		
		D54-4	SIO0000A1		BW	5/14/18	Y	O	3 x 3 x 1	glass chunk		GC			AG		F					5				100	1	5																		X		
D55		-	SIO0000A2	None sent.																																												
		D55-1	SIO0000A3		IB/CD	5/14/18	Y	O	7 x 6 x 1	glass fragment	P	GC		M	AG		P	OS				20				100	3	4																		X		
D56		-	SIO0000A4	rest of dredge (3 buckets)																																												
		D56-1	SIO0000A5		IB/CD	5/14/18	Y	P	12 x 7 x 16	pillow fragment	P	GC	1	M	GR	3	F	OS				1				100	2	4								X							X			X		
		D56-2	SIO0000A6		IB/CD	5/14/18	Y	P	10 x 6 x 5	pillow fragment	P	GC	0	M	GR	4	P	OS				2	5	2	2	95	2	4							Come from 50x60x40 pillow	X										X		
		D56-3	SIO0000A7		IB/CD	5/14/18	Y	P	6 x 5 x 5	pillow bud	P	GC	0	M	GV		P	F				1				100	2	3								X												
		D56-4	SIO0000A8		IB/CD	5/14/18	Y	O	2 x 2 x 2	glass fragment	A	AG	0		AG		F	F																												X		
		D56-5	SIO0000A9		IB/CD	5/14/18	Y	O	2 x 2 x 2	glass fragment	A	AG	0		AG		F	F																												X		
D57		-	SIO0000AA	rest of dredge (3 buckets)																																												
		D57-1	SIO0000AB		DZ	5/14/18	Y	P	14 x 13 x 8	irregular fragment of big pillow	A	GC			GR	4	F,P	F																	rock is aphanitic, but glass has	X							X			X		
		D57-2	SIO0000AC		DZ	5/14/18	Y	P	14 x 10 x 10	fragment of smaller pillow	P	GC		F	GR	5		OS								100	1	1							quality of glass: no information								X			X		
		D57-3	SIO0000AD		DZ	5/14/18	Y	P	10 x 7 x 6	small pillow	P	GC		M	GR	4	F	OS								100	1	2								X							X			X		
		D57-4	SIO0000AE		DZ	5/14/18	Y	O	4 x 2,5 x 0,8	looks like a glass rid		GC		F	AG		F, P	F								100	<1	<1							morphology: chunk											X		
		D57-5	SIO0000AF		DZ	5/14/18	Y	O	2 x 1,5 x 1,5	looks like a glass rid	P	GC		M	AG		F									100	1	2							morphology: chunk of glass											X		
D58		-	SIO0000AG	rest of dredge (1 bucket)																																												
		D58-1	SIO0000AH	yes	BW	5/15/18	N	P	15 x 5 x 3	fragments	P			M	NG			OS, AG								100	1	5							alteration halo is 5	X							X					
		D58-2	SIO0000AI		BW	5/15/18	N	P	7 x 7 x 5		P			M	GR	5		OS								100	1	5								X							X					
D59		-	SIO0000AJ	rest of dredge (1 bucket)																																												
		D59-1	SIO0000AK		BW	5/15/18	Y	MF	19 x 10 x 8		A	GC		A	GR	6	F	OS																		X										X		
		D59-2	SIO0000AL		BW	5/15/18	Y	MF	13 x 7 x 5	glass flow? Odd		GC			AG		F, P									100	2	5								X												
		D59-3	SIO0000AM		BW	5/15/18	Y	MF	8 x 6 x 5		P	GC		M	GR	4	F, P									100	2	5															X			X		
D60		-	SIO0000AN	rest of dredge (4 buckets)																																												
		D60-1	SIO0000AO		CD/IB	5/15/18	Y	P	10 x 5 x 5	pillow fragment	P	GC	1	M	GV		PD	OS					2	2	2	98	3	5							dimensions: full pillow= 40 x 30 x	X												
		D60-2	SIO0000AP		CD/IB	5/15/18	Y	P	6 x 5 x 4	pillow fragment	P	GC	2	M	GR	4	P	F					2	2	2	98	3	5								X							X			X		
		D60-3	SIO0000AQ		CD/IB	5/15/18	Y	O	3 x 3 x 4	glass nodule	P	GC	0	M	AG		PD	F								100	2	3							morphology: glass											X		
		D60-4	SIO0000AR		CD/IB	5/15/18	Y	O	3 x 3 x 3	glass fragment	P	GC	0	M	AG		P	OS					2	1	1	98	2	3							morphology: glass											X		
		D60-5	SIO0000AS		CD/IB	5/15/18	Y	O	3 x 6 x 2	glass fragment	P	GC	0	M	AG		P	OS								100	2	4							morphology: glass											X		
D61		-	SIO0000AT																																													
		D61-1	SIO0000AU	yes	BW	5/16/18	Y	O	1 x 0,5 x 0,25	small glass piece		AG			AG		F, P																													X		
		D61-2	SIO0000AV		BW	5/16/18	Y	O	1 x 0,25 x 0,25	small glass piece		AG			AG		P																													X		
D62		-	SIO0000AW	Rest of dredge																																												
		D62-1	SIO0000AX	yes	BW	5/16/18	Y	MF	15 x 12 x 5	drip textures	A	AG		A	GR	10	F	F																		X							X			X		
		D62-2	SIO0000AY	yes	BW	5/16/18	Y	MF	10 x 9 x 5		A	AG		A	GR	10	F	F																		X							X			X		
		D62-3	SIO0000AZ		BW	5/16/18	Y	O	4 x 2 x 2	glass chunk		AG			AG		F, P	F																												X		
		D62-4	SIO0000B0		BW	5/16/18	Y		3 x 2 x 3			AG			AG		F, P																													X		
D63		-	SIO0000B1	rest of dredge (3 buckets)																																												
		D63-1	SIO0000B2	yes	IB/CD	5/16/18	Y	P	10 x 10 x 5	pillow fragments	P	GC		F	GR	4	P		1							100	1	1							manganese crust: not totally	X							X			X		
		D63-2	SIO0000B3		IB/CD	5/16/18	Y	P	12 x 7 x 6	pillow fragments	A	GC	0	A	GV		PD	OS																		X												
		D63-3	SIO0000B4	yes	IB/CD	5/16/18	Y	P	10 x 7 x 4	pillow fragments	A	GC	1	A	GV		F	F																		X										X		
D64		-	SIO0000B5																																													
		D64-1	SIO0000B6		SA/DZ	5/16/18	Y	O	2 x 1,5 x 1	chunks	A	AG			AG		F										1	1							phenocryst mineralogy: 1 crystal of plag in one of the pieces											X		
D65		-	SIO0000B7	rest of dredge (3 buckets)																																												
		D65-1	SIO0000B8		BW	5/17/18	Y	P	17 x 11 x 9		A	AG		A	GR	3	F	OS																		X										X		
		D65-2	SIO0000B9		BW	5/17/18	N	P	12 x 8 x 7	pillow fragment	A	AG		A	GV			OS																		X							X					
		D65-3	SIO0000BA		BW	5/17/18	Y	O	3.5 x 2 x 1	glass chunk		AG			AG		F																													X		
		D65-4	SIO0000BB		BW	5/17/18	Y	O	3 x 2 x 2	glass chunk		AG			AG		F																													X		
		D65-5	SIO0000BC		BW	5/17/18	Y	SF	11 x 7 x 6		A	AG		A	FR	4	F	OS																		X										X		
D66		-	SIO0000BD	rest of dredge (3 buckets)																																													
		D66-1	SIO0000BE		BW	5/18/18	Y	P	6 x 2 x 2	bud	A	AG		A	GV		P	OS																		X										X		
		D66-2	SIO0000BF		BW	5/18/18	Y	P	6 x 4 x 2	bud	A	AG		A	GV		PD,P	OS																		X												
		D66-3	SIO0000BG		BW	5/18/18	Y	O	2 x 2 x 0.5	glass piece		AG			AG		F																													X		
		D66-4	SIO0000BH		BW	5/18/18	Y	P	2 x 2 x 2	bud	A	AG		A	GV		F	F																		X										X		
		D66-5	SIO0000BI		BW	5/18/18	Y	P	3 x 2 x 1	bud	A	AG		A	GV		F	OS																		X												
		D66-6	SIO0000BJ		BW	5/18/18	N	P	9 x 7 x 5	fragment	A			A				OS,EA																		X							X					

Table 3. Samples taken by other participants

SAMPLES TAKEN BY OTHER CRUISE PARTICIPANTS

Participant	Email	ID	IGSN	Notes
Iker Blasco	i.blasco@igme.es	D2	SIO00008K	
Iker Blasco	i.blasco@igme.es	D8-1	SIO00008L	
Iker Blasco	i.blasco@igme.es	D8-3*	SIO00008M	Same rock type as D8-3 BEN, different samples. Hand sample and slab
Iker Blasco	i.blasco@igme.es	D14	SIO00008N	Hand sample and slab
Iker Blasco	i.blasco@igme.es	D15	SIO00008O	
Iker Blasco	i.blasco@igme.es	D18-1**	SIO00008P	Shared sample with DOM, diferent sample numbers. Crust sample
Iker Blasco	i.blasco@igme.es	D18-2**	SIO00008Q	Shared sample with DOM, diferent sample number. Crust sample
Iker Blasco	i.blasco@igme.es	D18-3**	SIO00003U	Shared sample with BEN, diferent sample number. Crust sample
Iker Blasco	i.blasco@igme.es	D18-4	SIO00008R	Same rock type as D18-6 DOM, diferent sample number. Crust sample
Iker Blasco	i.blasco@igme.es	D18-5	SIO00008S	Same rock type as D18-6 DOM, diferent sample number. Crust sample
Iker Blasco	i.blasco@igme.es	D18-6	SIO00008T	Same rock type as D18-6 DOM, diferent sample number. Crust sample
Iker Blasco	i.blasco@igme.es	D18-7*	SIO00003W	Half sample of D18-3 BEN. Crust sample
Iker Blasco	i.blasco@igme.es	D20	SIO00008U	
Iker Blasco	i.blasco@igme.es	D24	SIO00008V	Thin crust sample
Iker Blasco	i.blasco@igme.es	D30	SIO00008W	Black smoker piece
Iker Blasco	i.blasco@igme.es	D30	SIO00008X	Glass
Iker Blasco	i.blasco@igme.es	D34-1	SIO00008Y	Crust sample
Iker Blasco	i.blasco@igme.es	D34-2	SIO00008Z	Crust sample
Iker Blasco	i.blasco@igme.es	D35	SIO00000C0	Crust sample
Iker Blasco	i.blasco@igme.es	D42	SIO00000C1	Thin crust sample
Iker Blasco	i.blasco@igme.es	D46	SIO00000C2	
Iker Blasco	i.blasco@igme.es	D47-1*	SIO00000C3	Same rock type as D47-1 BEN, diferent samples. Three samples
Iker Blasco	i.blasco@igme.es	D49	SIO00000C4	
Iker Blasco	i.blasco@igme.es	D50**	SIO00000C5	Shared forams with DOM
Iker Blasco	i.blasco@igme.es	D54	SIO00000C6	
Iker Blasco	i.blasco@igme.es	D58-1*	SIO00000C7	Same rock type as D58-1 BEN, diferent samples.
Iker Blasco	i.blasco@igme.es	D62	SIO00000C8	Glass
Iker Blasco	i.blasco@igme.es	D63-HUGE	SIO00000C9	2 crust samples taken from huge rock samples as D63-HUGE or D63-1
Iker Blasco	i.blasco@igme.es	D63	SIO00000CA	Pillow with calcaerous clay inside
Iker Blasco	i.blasco@igme.es	D66-7*	SIO00000CB	Same rock type as 66-6 BEN, diferent samples
Iker Blasco	i.blasco@igme.es	D66.7**	SIO00000BJ	Shared sample with BEN
Joe Cann	joe.cann@gmx.co.uk	D18-12	SIO00000CC	same rock as SA, shared sample, same IGSN. JC has 1 pc, SA has 2 pcs
Joe Cann	joe.cann@gmx.co.uk	D18-23	SIO00000CD	1/2 piece only. JC has 1/2 only. Not sure who has other half
Joe Cann	joe.cann@gmx.co.uk	D18-24	SIO00000CE	old rock. JC has whole piece
Joe Cann	joe.cann@gmx.co.uk	D41-4	SIO00000CF	chlorite margine. Handwritten on sample D43-1 but description doesn't match
Joe Cann	joe.cann@gmx.co.uk	D41-5	SIO00000CG	
Joe Cann	joe.cann@gmx.co.uk	D41-6	SIO00000CH	SA has 1/2, JC has 1/2. basalt conglomerate
Sara Afshar	afshar_sara@yahoo.com	D18-10	SIO00000CI	same rock as DZ, shared sample, same IGSN
Sara Afshar	afshar_sara@yahoo.com	D18-12	SIO00000CC	same rock as JC, shared sample, same IGSN
Sara Afshar	afshar_sara@yahoo.com	D18-13	SIO00000CJ	same rock as IB, shared sample, same IGSN
Sara Afshar	afshar_sara@yahoo.com	D18-14	SIO00000CK	same rock type as EL D18-11
Sara Afshar	afshar_sara@yahoo.com	D18-15	SIO00000CL	whole rock, not cut, crust
Sara Afshar	afshar_sara@yahoo.com	D18-16	SIO00000CM	whole rock, with crust
Sara Afshar	afshar_sara@yahoo.com	D18-17	SIO00000CN	crust with clay possibly similar to D18-8 of DZ and IB
Sara Afshar	afshar_sara@yahoo.com	D41-6	SIO00000CH	SA has 1/2, JC has 1/2
Sara Afshar	afshar_sara@yahoo.com	D41-7		SA has whole rock
Sara Afshar	afshar_sara@yahoo.com	D41-8	SIO00000CO	SA has a small piece, same rock type as JC D41-5
Sara Afshar	afshar_sara@yahoo.com	D41-9	SIO00000CP	SA has a small piece, same rock type as JC D41-5
Sara Afshar	afshar_sara@yahoo.com	D41-10	SIO00000CQ	SA has whole rock
Sara Afshar	afshar_sara@yahoo.com	D41-11	SIO00000CR	SA has a piece, similar to D41-12
Sara Afshar	afshar_sara@yahoo.com	D41-12	SIO00000CS	SA has a piece, similar to D41-11
Sara Afshar	afshar_sara@yahoo.com	D41-13	SIO00000CT	SA has whole rock
Sara Afshar	afshar_sara@yahoo.com	D41-14	SIO00000CU	SA has whole rock
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-2	SIO00000CV	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-6	SIO00000CW	pillow fragment
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-8	SIO00000CX	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-11	SIO00000CY	pice of bud
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-15	SIO00000CZ	pillow fragment
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-17	SIO00000D0	station glass
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D18-1	SIO00003U	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D18-6	SIO00008T	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D18-7	SIO00000D1	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D18-8	SIO00008P	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D18-9	SIO00008Q	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D18-10a	SIO00000D2	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D18-10b	SIO00000D2	
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-25	SIO00000D3	pillow fragment
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-33	SIO00000D4	Forams
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-35	SIO00000D5	Forams ooze
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-35	SIO00000D6	Rock + glass
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-49	SIO00000D7	Small amount of sediment with forams
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-50	SIO00000C5	Forams
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-52	SIO00000D8	Forams
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-57	SIO00000D9	Forams
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-61	SIO00000DA	pillow fragment
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-62	SIO00000DB	pillow fragment
Dominik Zawadzki	dominik.zawadzki@usz.edu.pl	D-63	SIO00000DC	
Elvira Latypova	ehllatypova@yandex.ru	D18-8(E)	SIO00000DD	(Crust samples)
Elvira Latypova	ehllatypova@yandex.ru	D18-1(E)	SIO00000DE	(whole rock w/ clay layers and Mn crust)
Elvira Latypova	ehllatypova@yandex.ru	D18-11(E)	SIO00000DF	(basalt w/ thin crust, alteration halo(core))
Elvira Latypova	ehllatypova@yandex.ru	D18-6(E)	SIO00000DG	(whole rock w/ 2mm crust, olivine-rich, outer margin of larger and more abundant phenos)
Elvira Latypova	ehllatypova@yandex.ru	D18-18(E)	SIO00000DH	1/2 of the rock with thin Mn crust, ol-rich, 2 alteration halos, crack and vesicles
Elvira Latypova	ehllatypova@yandex.ru	D18-19(E)	SIO00000DI	1/2 of the rock with thin Mn crust, ol-rich, plg-rich, 2 alteration halos, a lot of cracks; vesicles
Elvira Latypova	ehllatypova@yandex.ru	D18-20 (E)	SIO00000DJ	1/2 of the rock with ol, plg, thin Mn crust; alteration halo, a lot of cracks and vesicles; looks more fresh than D18-20
Elvira Latypova	ehllatypova@yandex.ru	D18-21 (E)	SIO00000DK	1/2 of the rock with ol, a lot of plg (>10%); with thin Mn crust, crack in the middle of the rock
Elvira Latypova	ehllatypova@yandex.ru	D18-22 (E)	SIO00000DL	1/2 of the rock with with thick Mn crust (8 mm), a lot of plg (>5%) , crack in the middle of the rock, vesicles
Elvira Latypova	ehllatypova@yandex.ru	D25-3(E)	SIO00000DM	ropy lava with Mn crust +sand+forams(?)
Elvira Latypova	ehllatypova@yandex.ru	D35(E)-1	SIO00000DN	Mn crust
Elvira Latypova	ehllatypova@yandex.ru	D35(E)-2	SIO00000DO	rock (basalt)+glass+Mn crust(7mm)+sand/ Breccia
Elvira Latypova	ehllatypova@yandex.ru	D35(E)-3	SIO00000DP	Mn crust with a little piece of glass and rock (basalt)
Elvira Latypova	ehllatypova@yandex.ru	D62	SIO00000DQ	glass

11. Appendices

Appendix A. Participants

Captain and Crew		**Science Party**	
Murline, David	Master	Afshar,Sara	Scripps
lawrence, Ian	1st Mate	Alodia, Gabriella	Leeds University
Robert Freels	2nd Mate	Blasco, Iker	Geological Survey of Spain
Christian, Randy	3rd Mate	Cann, Johnson	Leeds University (emeritus)
Kenter Darius	Boatswain	Convery, James	UCSD
Griffin, Jeff	AB	Curry, Scott	Woods Hole
Szmagalski, Thomas	AB	Dunham, Charles	Leeds University
Putnam Aaron	AB	Huey, Mary	UCSD
Dunigan, Elysia	OS	Klein, Emily	Duke University
Smith, Mark	Sr. Cook	Latypova, Elvira	University of St. Petersberg
Jordan, John	Cook	Manger, Josh	UCSD
Peer, Matt	Chief Eng	Smith, Deborah	NSF
Kane, Brian	1st Asst Eng	Wernette, Benjamin	Duke University
Swader, Sue	2nd Eng	Zawadzki, Domnik	University of Szczecin
Sankoh, Sahr	3rdAsst Eng		
Goodbody, Adam	Electrician		
Will Brown	Oiler		
Sampson, Buck	Oiler		
Jackson, Travis	Oiler		
Sherman, Henry	Oiler		

Appendix B. Daily Diary

20th April 2018, Julian Day 110

Leave Manzanillo at 1545 local time

21 – 23 April 2018, 111-113

In transit to work area

24 April, 114

Arrive in the work area.

Test dredging without a pinger. The test is successful (see techniques section below). Dredge 1 situated in what became segment 7. Start surveying bathymetry, magnetic field and gravity in the part of the Gore between 99° 40'W and the Hess Deep at the west tip of the Gore at 101° 40'W.

25-28 April, 115-118

Conducting the survey, finishing it close to the Hess Deep. It covered the area of the gore between 101°40'W and 99°40'W.

29 April, 119

Dredges 2 to 4 are on the axis of the East Pacific Rise immediately next to Hess Deep, to provide a geochemical reference for the dredges inside the Gore.

We receive a distress call from a disabled catamaran with two on board about 150 miles to the northwest. They are short of fuel and food. We set off on our rescue mission late that evening.

30 April, 120

We reach the catamaran about 1230 local time, provide the two men on board with 200 gallons of fuel and some food so that they can reach Galapagos, and leave about 1700.

1 May, 121

Arrive back on site. Dredges 5 and 6 are on segment 2 in over 5000m of water, just east of Hess Deep. Superimpose on our bathymetry a map of the backscatter intensity from the sidescan to show where bare rock is likely to be exposed. This becomes very useful later.

2 May 122

Continue dredging with dredges 7, 8 and 9 close together on segment 2. Then 10, 11, 12, 13 and 14 in segment 3. Unless otherwise commented on, all of the dredges between 1 and 60 were targeted at the axis of the spreading segments numbered 2 to 9. These axial segments reliably yielded fresh to very fresh basaltic lavas and fresh glasses.

3 May 123

Dredge 18 was sited off axis on a local high that might have exposed deeper levels in the crust, but instead appeared to return rather weathered basalt. On the axis of segment 4 we made the closely spaced dredges 15, 16, 17 and 19.

4 and 5 May, 124 and 125

Dredges 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31 and 32 are a closely-spaced series along the long segment 5 that extends into the morning of 6 May.

6 and 7 May, 126 and 127

Dredge 33 was on a ridge between segments 5 and 6 attempting to recover some deep-seated rocks, but failed to recover anything. Dredges 34, 35, 36, 37, 38, 39 and 40 were another closely-spaced line along the axis of segment 6. Dredge 41 was targeted at a ridge between segments 6 and 7, seeking deeper-seated rocks and returned some metabasalts with chlorite veins.

8 May, 128

Dredges 42,43, 44, 45, 46, 47 and 48 were a closely-spaced series along segment 7.

9 -12 May, 129-132

Conducting a survey east of the earlier one, covering the area of the gore between 99°40'W and 98°25W. Together the two surveys covered an area close to 50,000 km^2.

13 May, 133

Dredges 49, 50 and 51 were made on the axis of Segment 9. Dredge 52 was made on a ridge between segments 8 and 9 and returned empty. Dredge 53 was on the axis of Segment 8.

14 May, 134

Dredges 54, 55, 56, 57 were a series along the axis in segment 8 and dredges 58, 59 and 60 were made in segment 7.

15 May, 135

Transect across our main area into the area around Dietz Deep.

16 May, 136

Dredges 61, 62, 63, 64, 65 were targeted around Dietz Volcanic Ridge and the East Pacific Rise crest close to it. They established that the ridge is in fact volcanic and active too, since very fresh glasses were recovered from the crest of the ridge. A winch malfunction halted dredge 66, so we began a small magnetic survey of an area of the Galapagos Microplate between Dietz Deep and Hess Deep.

17 May, 137

Continuing the magnetic survey.

18 May, 138

Dredge 66 on the east limb of the of the 3.5°N overlapping spreading center on EPR. Ended science days, began transit to San Diego with magnetometer deployed

Appendix C

EM122 processing script to generate bathymetry and gravity scripts

Bathymetry:

```
/bin/ls -1 *all | awk '{print $1" 58"}' > datalist.mb-1
mbkongsbergpreprocess -I datalist.mb-1 -V
/bin/ls -1 *mb59 | awk '{print $1" 59"}' > datalist.mb-1
mbdatalist -o -v -z
mbclean
mbprocess -V
mbgrid -Idatalistp.mb-1 -A2 -F5 -N -C2 -OSurveyD -V
```

Sidescan:

```
mbbackangle -I datalist.mb-1 \
    -A1 -A2 -Q -V -N87/86.0 -R50 -G2/85/1500.0/85/100
mbset -PAMPCORRFILE:datalist.mb-1_tot.aga
mbset -PSSCORRFILE:datalist.mb-1_tot.sga
mbprocess
mbfilter -Idatalistp.mb-1 -S2/5/3
mbmosaic -Idatalistp.mb-1 -A4F -N -Y6 -F0.05 -OSS -V
```

Magnetics

Processing steps

SeaSPy magnetometer data collected by the BOB software does not correctly interpolate GPS data accurately, making it necessary to use the Serial Instruments raw feed instead. Once the GPS and magnetometer information was combined, the position of the magnetometer was interpolated relative to the ship. The magnetic anomaly could then be calculated by using the IGRF 2015 dataset to remove the background field.

Script to combine GPS and magnetometer data:

```
#!/bin/bash

################## combine_gps_mag.sh ################################
############### Charlie Dunham 22/04/2018 ############################
####
#### A script to combine serial instrument GPS and magnetometer data
#### To run: ./combine_gps_mag.sh MAGFILE GPSFILE
#### Script has been written to work with the bd GPS system, may not work
#### with other GPS
#### Outputs a file with four columns: lon lat bearing mag
```

```
rm -rf mag.txt
rm -rf gps.txt
rm -rf combined.txt
rm -rf gps_full.txt
rm -rf raw_gps_bd.xym


magfile=$1
gpsfile=$2


######## Strip time info and mag data
awk '{print $2, $3}' $magfile | sed 's/://g' | sed 's/F//' | cut -c 9- \
| sed -r -e 's/^.{8}/&0/' | sed -r -e 's/^.{11}/& /' | awk '{print $1, $3}' > mag.txt


######### Strip time info and lat lon from GPS
grep 'GNGGA' $gpsfile | awk -F ',' '{print $5, $3, $2}' | sed -r -e 's/^.{5}/& /' | sed -r -e 's/^.{7}/& /' \
| sed -r -e 's/^.{21}/& /' | sed -r -e 's/^.{23}/& /' | awk '{print $1, $3, $4, $6, $7}' | sed '/^$/d;s/[[:blank:]]//g' \
| sed -r -e 's/^.{13}/& /' | sed -r -e 's/^.{26}/& /' | sed -r -e 's/^.{3}/& /' | sed -r -e 's/^.{17}/& /' \
 > temp.txt


awk '{$2=sprintf( "%.9i", $2/6)} 1' temp.txt | awk '{$4=sprintf( "%.9i", $4/6)} 1' | sed '/^$/d;s/[[:blank:]]//g' \
 | sed -r -e 's/^.{3}/&./' | sed -r -e 's/^.{13}/& /' | sed -r -e 's/^.{16}/&./' | sed -r -e 's/^.{26}/& /' \
 | sed -r -e 's/^.{0}/&-/' | awk '{print $3, $1, $2}' > gps.txt

######## Combine bearing with GPS data
grep 'GNVTG' $gpsfile | awk -F ',' '{print $2}' > bearing.txt
paste -d" " gps.txt bearing.txt | cut -d" " -f1-3,4 > gps_full.txt

######### Combine corresponding GPS and mag readings  > Lots of sed to edit format of lat lon etc
join gps_full.txt mag.txt | awk '{print $2, $3, $4, $5}' > lon_lat_bearing_mag.txt


rm -rf temp.txt
```

Script to interpolate the position of the magnetometer:

```
clear all
%%%% A script to interpolate the position of the magnetometer given the
%%%% tow length and average bearing.
%%%% Split day files into individual lines before running

%%%% Input file containing lon lat bearing mag for each individual line
fid=fopen('lon_lat_bearing_mag.txt');
m = fscanf(fid, '%f %f %f %f',[4,inf]);
fclose(fid);

m = m';


lat = m(:,2);
lon = m(:,1);
heading =m(:,3);
mag = m(:,4);

%%%%% input the mean bearing for the line
bearing = 289.75;


hm = input('Please input the magnetometer tow length in m: ');
h = hm/111139;
fid1=fopen('lon_lat_mag.txt', 'w');
for i=1:length(lat);
    %fprintf('%f\n', lat(i))
```

```
    if bearing <= 90
        theta = bearing;
        x1 = h*sin(theta);
        y1 = h*cos(theta);
        ym = lat(i) - y1;
        xm = lon(i) - x1;
        fprintf(fid1, '%f %f %f\n', xm, ym, mag(i));
    elseif bearing >= 90 && bearing <=180
        theta = 180 - bearing;
        x1 = h*sin(theta);
        y1 = h*cos(theta);
        ym = lat(i) + y1;
        xm = lon(i) - x1;
        fprintf(fid1,'%f %f %f\n', xm, ym, mag(i));
        %fprintf('%f %s\n', bearing(i), 'test')
    elseif bearing >= 180 && bearing <=270
        theta = 180 + bearing;
        x1 = h*sin(theta);
        y1 = h*cos(theta);
        ym = lat(i) + y1;
        xm = lon(i) + x1;
        fprintf(fid1,'%f %f %f\n', xm, ym, mag(i));
    else
        theta = 360 - bearing;
        x1 = h*sin(theta);
        y1 = h*cos(theta);
        ym = lat(i) - y1;
        xm = lon(i) + x1;
        fprintf(fid1,'%f %f %f\n', xm, ym, mag(i));
    end
end


fid1=fopen('lon_lat_mag.txt');
n = fscanf(fid1, '%f %f %f',[3,inf]);
fclose(fid1);


n = n';

lon1 = n(:,1);
lat1 = n(:,2);
mag =n(:,3);


plot(lon1,lat1);
hold on
plot(lon,lat), legend('MAG','GPS');
```

Processing to recover magnetic anomaly profile for each line:

```
% open data raw data and plot

clear all
close all

load line_104_mag.txt  % read in raw data: lat

tn = line_104_mag;

figure
plot(tn(:,1), tn(:,2)) % plot lat lon to check looks sensible

figure
plot(tn(:,3)) % plot anomaly to check looks sensible
```

```
%% ------------------------------------------------------------

% choose data within study area (may not be necessary)

lat1=1.00
lat2=2.5
lon1=-102.5
lon2=-101.000

studyarea = find(tn(:,1) > lon1 & tn(:,1) < lon2 & tn(:,2) > lat1 & tn(:,2) < lat2);

e=tn;

e(studyarea,:)=[];

plot(e(:,1), e(:,2),'.');

%% ------------------------------------------------------------

% calculate anomaly from the total field data using 2015 IGRF
% uses Mag_IGRF.m and magfd.m - check inputs

[A,elongs,lats]=Mag_IGRF(tn(:,2),tn(:,1),tn(:,3));

mag_igrf = [elongs, lats, A];

plot(A)

grdwrite2(elongs, lats, A, 'mag16_anomaly.grd');

      fid = fopen('mag4surface.xyz','wt');

      fprintf(fid,'%8.4f %8.4f %8.4f\n',mag_igrf');

      fclose(fid);
%% ------------------------------------------------------------------

% downsample the magnetic anomaly data to one sample per minute
% for plotting purposes.

fid=fopen('mag4surface.xyz');
m = fscanf(fid, '%f %f %f',[3,inf]);
fclose(fid);

m = m';


lon = m(:,1);
lat = m(:,2);
mag = m(:,3);

fid1=fopen('line_104_ds.txt', 'w');
for i=1:60:length(lon)
   magneg = mag(i)*-1;
   fprintf(fid1, '%f %f %f\n',lon(i), lat(i), magneg);
end
```

Gravity

Processing steps

The gravity processing steps is divided into 5 steps: (1) Raw data processing, (2) Calculating FAA from observed gravity, (3) Gridding, masking, and padding FAA with satellite data, (4)

Thermal gravity modelling – from lithospheric cooling, and (5) Calculating BA, MBA, RMBA, and RCT.

1. Raw data processing (GEF → xygbv)

In this step, we read the GEF data from the gravimeter as well as raw data from the GPS, and write them into an xygbv file which contains longitude, latitude, observed gravity, ship bearing (course over ground – COG), and ship velocity (speed over ground – SOG) for every single day. Both COG and SOG will be used for Eotvos correction in the next step. Daily data is processed before separated into a number of survey lines.

Inputs: GPS data (bd982*.raw), Gravity data (*.GEF)
Output: ASCII data containing longitude, latitude, observed gravity, cog, and sog (*.xygbv)

Shell code:

```
   #!/bin/bash

   rm -rf gps_temp.txt
   rm -rf gps_use.txt
   rm -rf grav_fgs.tg

   #######   GPS: print time stamp, lon (dms), lat (dms)

   ## Strip lon lat time from raw files

   grep 'GNGGA' bd982-1_20180426000000.raw | awk -F ',' '{print $5, $3, $2}'
| sed -r -e 's/^.{5}/& /' | sed -r -e 's/^.{7}/& /' | sed -r -e 's/^.{21}/&
/' | sed -r -e 's/^.{23}/& /' | awk '{print $1, $3, $4, $6, $7}' | sed
'/^$/d;s/[[:blank:]]//g' | sed -r -e 's/^.{13}/& /' | sed -r -e 's/^.{26}/&
/' | sed -r -e 's/^.{3}/& /' | sed -r -e 's/^.{17}/& /' \ > gps_temp.txt

   ## Convert dms to decimal degrees

   awk '{$2=sprintf( "%.9i", $2/6)} 1' gps_temp.txt | awk '{$4=sprintf(
"%.9i", $4/6)} 1' | sed '/^$/d;s/[[:blank:]]//g' | sed -r -e 's/^.{3}/&./' |
sed -r -e 's/^.{13}/& /' | sed -r -e 's/^.{16}/&./' | sed -r -e 's/^.{26}/&
/' | sed -r -e 's/^.{0}/&-/' | awk '{print $3, $1, $2}' > gps.txt

   ## Combine SOG COG with GPS data

   grep 'GNVTG' bd982-1_20180426000000.raw | awk -F ',' '{print $2, $6}' >
bearing.txt
   paste -d" " gps.txt bearing.txt > gps_use.txt

   #######   GRAVITY: printing time stamp, grav

   for file in 20180426*.GEF ; do
   grep 'FGS' $file | awk '{print $3, $4}' | sed 's/://g' | sed -r -e
's/^.{6}/& /' | awk '{print $1, $3}' | sed -r -e 's/^.{6}/&.00/' >>
grav_fgs.tg

   #######   COMBINE GPS and Grav

join gps_use.txt grav_fgs.tg | awk '{print $2, $3, $6, $4, $5}' >
```

```
grav_0426.xygbv

   #######   Manual steps
   ## Plot daily gravity to see where the vessel makes a turn, which can be
seen in the gradual change of COG
   ## After this step we should have gravity data in each survey line, which
will be used to calculate FAA
```

2. Calculate FAA from observed gravity (xygbv → xyg)

The second step is to calculate Free-Air Anomaly (FAA) from the observed gravity by applying a sequence of correction: (1) Eotvos correction, correcting the effect of a moving instrument; (2) Latitude correction, subtracting theoretical gravity across the globe from the observed values – leaving only the anomalies, and; (3) 1-dimensional Gaussian filter, to smooth-out the noisy data. This Matlab code needs signal processing plugin.

Input: Gravity data from Sequence #1 (`*.xygbv`)
Output: ASCII FAA data (`*.xyg`)

Matlab code:

```
close all;
clear all;
clc;

%% load line data

dat=load('grav_line_01.xygbv');

lon=dat(:,1);
lat=dat(:,2);
grv=dat(:,3);
cog=dat(:,4);
sog=dat(:,5);

% latitude in radians

latr=degtorad(lat);

% cog in radians

cogr=degtorad(cog);

%% apply eotvos correction

for i=1:length(grv)

c_eot(i)=(((7.508*sog(i)).*(cos(latr(i)))).*(sin(cogr(i))))+(0.004154.*(sog(i
).^2));
    g_eot(i)=grv(i)+c_eot(i);
end

%% apply latitude correction (WGS84)
```

```
for i=1:length(grv)
    c_wgs(i)=978032.67714*((1+(0.00193185138639.*(sin(latr(i)).^2)))/((1-
(0.006694437999013.*((sin(latr(i)).^2)))).^0.5));
    g_wgs(i)=g_eot(i)-c_wgs(i);
end

%% apply Gaussian filter: needs signal processing plugin for Matlab

% Gaussian window

w=gausswin(600); % filter every 10 minutes = 600 s

% filter
% cut the first 1000 data - ship still turning
% filtered data has offset of 250 s compared to raw data

lonf=lon(1001:end-250);
latf=lat(1001:end-250);
g_wgsf=g_wgs(1001:end);

g_faa=filter(w,300,g_wgs)';
g_faaf=g_faa(1251:end);

%% write file

fid1=fopen('grav_faa_line01.xyg', 'w');
for i=1:length(lonf)
    fprintf(fid1, '%f %f %f\n',lonf(i), latf(i), g_faaf(i));
end

%% plot file

figure
plot(lat,grv,'.yellow')
xlim([1.5 3])
title('Observed Gravity')
xlabel('Latitude (degree)')
ylabel('Gravity (mgal)')

figure
plot(latf,g_wgs(1001:end-250),'.yellow')
xlim([1.5 3])
hold on
plot(latf,g_faa(1251:end),'black')
title('Free Air Anomaly')
xlabel('Latitude (degree)')
ylabel('Gravity (mgal)')

%% Next step: put all FAA lines in one ASCII XYZ data - either using Matlab
or Shell code
```

3. Grid, mask, and pad FAA (xyg → grd)

Having all the gravity data of each survey line, an FAA *.grd data is created by: (1) Interpolating the *.xyg data using blockmean and surface function from GMT every 1 arc-

minute; (2) Creating a mask by interpolating the *.xyg data using nearneighbor and grdmask function from GMT, and; (3) Padding the 'missing' FAA information with satellite data, downloaded from the TOPEX XYZ Grid extraction tool (http://topex.ucsd.edu/cgi-bin/get_data.cgi). The code below is also used to plot various gridded files from the following sequences, with several modifications.

Inputs: FAA data from all lines (surv_faa_mixed.xyg), satellite data of 1 arc-minute resolution (mod_faa_sandwell.xyg)

Output: Gridded FAA data (surv_faa_padded.grd)

GMT Code:

```
   set ps=surv_faa_padded.ps
   set region=-R-102.02/-98.44/1.40/3.20
   set scale=-JM24

   rem load and write FAA files from survey

   set file1=surv_faa_mixed.xyg

   set file2=surv_faa_surface.grd
   set file3=surv_faa_nn.grd
   set file4=surv_mask.grd
   set file5=surv_faa_masked.grd

   rem load and write Satellite FAA and padded files

   set file6=mod_faa_sandwell.xyg
   set file7=mod_faa_sandwell.grd
   set file8=surv_faa_padded.grd

   rem load bathymetry and survey track if needed

   set bathy=Grid_all_15May.grd
   set track=surv_faa_tracks_mixed.xy

   rem make colorbar

   gmt makecpt -Chaxby -T-55/35/0.1 > g.cpt

   rem create surface grid (1 arc-minute)

   gmt blockmean %file1% -I1m %region% | surface -I1m -T.5 -
Gsurv_faa_surface.grd %region%

   rem mask grid

   gmt nearneighbor %file1% %region% -I1m -S15k -N8 -Gsurv_faa_nn.grd
   gmt grdclip %file3% -Gsurv_mask.grd -Sa39/NaN -Sb39/0 -V
   gmt grdmath %file2% %file4% SUB = %file5%

   rem pad grid with satellite data

   gmt blockmean %file6% -I1m %region% | surface -I1m -T.5 %region% -
```

```
Gmod_faa_sandwell.grd
   gmt grdmath %file5% %file7% AND = surv_faa_padded.grd

   rem plot grid

   gmt grdimage %region% %file8% %scale% -Cg.cpt -K > %ps%
   gmt grdcontour %bathy% %scale% %region% -C250 -A1000+f10p -O -K >> %ps%

   rem add seismicity and focal mechanism if needed

   rem gmt psxy %region% %scale% ISC_Earthquake_Coordinates.txt -W -St0.15c -
Gred -O -K >> %ps%
   rem gmt psmeca %region% %scale% GCMT_psmeca_nolabel.txt -Sm0.35c -Gblack -
W -T0 -O -K >> %ps%

   rem build data frame and scale bar

   gmt pscoast %region% %scale% -Bg.5 -B.5 -BWeSn+t"FAA" -W0.5p -O -K -
Lx22/13.5/+c2+w50k+l >> %ps%

   rem build color bar

   gmt psscale -D12/16/20/0.5h -O -Cg.cpt -B10/:mgal: -K >> %ps%

   rem add survey tracks if needed

gmt psxy %track% %region% %scale% -Sc0.03c -Gwhite -O -K >> %ps%
```

4. Model thermal gravity from lithospheric cooling

In order to obtain Residual Mantle Bouguer Anomaly (RMBA), we need to subtract the gravity effects from the lithospheric cooling from the Mantle Bouguer Anomaly (MBA). This gravity effects is called the 'Thermal Anomaly,' calculated from the age of lithosphere. The age of lithosphere itself can be modelled by tracing the centre of the ridge (i.e. the 'zero age') in QGIS, export it into ASCII XY file, and interpolate it based on the ages of the Brunhes-Matuyama, Matuyama-Gauss, and Gauss-Gilbert reversals.

Input: ASCII XY file (`age_zero.xy`) digitized from bathymetry file in QGIS
Output: Thermal gravity model (`mod_litho_norm.grd`)

Matlab Code – to produce ages in each reversal:

```
   %% Computing ages in major magnetic reversals
   % Gabriella Alodia
   % Modified May 2018
   % This code computes the age of lithosphere from digitized (ASCII) zero
age (ridge axis). Parameter needed: spreading rate.
   %%

   close all
   clear all
   clc
```

```
%% load zero age

a=load('age_zero.xy');

lon=a(:,1);
lat=a(:,2);
age=zeros(length(lon),1);

figure; plot(lon, lat)

a_0=[lon lat age];

%% Brunhes, Matuyama, Gauss, Gilbert (with Nunivak) ages

ABr=0.78;
AMa=2.59;
AGa=3.59;
AGi=4.47;

%% make Brunhes-Matuyama reversal plots

% parameters

spr=40; % spreading rate, km/m.a.

lins=degtorad(10);  % lineation in radians
d_bm=(spr*ABr/2)/111;     % distance in degrees

% calculate North

for i=1:length(lon)
    lon_BMN(i)=lon(i)+d_bm*sin(lins);
    lat_BMN(i)=lat(i)+d_bm*cos(lins);
    age_BM(i)=0.78;
end

hold on; plot(lon_BMN, lat_BMN)

a_BMN=[lon_BMN' lat_BMN' age_BM'];

% calculate South

for i=1:length(lon)
    lon_BMS(i)=lon(i)+d_bm*sin(lins+degtorad(180));
    lat_BMS(i)=lat(i)+d_bm*cos(lins+degtorad(180));
end

hold on; plot(lon_BMS, lat_BMS)

a_BMS=[lon_BMS' lat_BMS' age_BM'];

%% make Matuyama-Gauss reversal plots

% parameters

d_mg=(spr*(AMa-ABr)/2)/111;     % distance in degrees
```

```
% calculate North

for i=1:length(lon)
    lon_MGN(i)=lon_BMN(i)+d_mg*sin(lins);
    lat_MGN(i)=lat_BMN(i)+d_mg*cos(lins);
    age_MG(i)=2.59;
end

hold on; plot(lon_MGN, lat_MGN)

a_MGN=[lon_MGN' lat_MGN' age_MG'];

% calculate South

for i=1:length(lon)
    lon_MGS(i)=lon_BMS(i)+d_mg*sin(lins+degtorad(180));
    lat_MGS(i)=lat_BMS(i)+d_mg*cos(lins+degtorad(180));
end

hold on; plot(lon_MGS, lat_MGS)

a_MGS=[lon_MGS' lat_MGS' age_MG'];

%% make Gauss-Gilbert reversal plots

% parameters

d_gg=(spr*(AGa-AMa)/2)/111;     % distance in degrees

% calculate North

for i=1:length(lon)
    lon_GGN(i)=lon_MGN(i)+d_gg*sin(lins);
    lat_GGN(i)=lat_MGN(i)+d_gg*cos(lins);
    age_GG(i)=3.59;
end

hold on; plot(lon_GGN, lat_GGN)

a_GGN=[lon_GGN' lat_GGN' age_GG'];

% calculate South

for i=1:length(lon)
    lon_GGS(i)=lon_MGS(i)+d_gg*sin(lins+degtorad(180));
    lat_GGS(i)=lat_MGS(i)+d_gg*cos(lins+degtorad(180));
end

hold on; plot(lon_GGS, lat_GGS)

a_GGS=[lon_GGS' lat_GGS' age_GG'];

%% make Gilbert-Nunivak reversal plots
% useful for interpolation

% parameters
```

```
   d_gg=(spr*(AGi-AGa)/2)/111;      % distance in degrees

   % calculate North

   for i=1:length(lon)
       lon_GNN(i)=lon_GGN(i)+d_gg*sin(lins);
       lat_GNN(i)=lat_GGN(i)+d_gg*cos(lins);
       age_GN(i)=4.47;
   end

   hold on; plot(lon_GNN, lat_GNN)

   a_GNN=[lon_GNN' lat_GNN' age_GN'];

   % calculate South

   for i=1:length(lon)
       lon_GNS(i)=lon_GGS(i)+d_gg*sin(lins+degtorad(180));
       lat_GNS(i)=lat_GGS(i)+d_gg*cos(lins+degtorad(180));
   end

   hold on; plot(lon_GNS, lat_GNS)

   a_GNS=[lon_GNS' lat_GNS' age_GN'];

   %% compile all

   age_xyz=[a_0; a_BMN; a_BMS; a_MGN; a_MGS; a_GGN; a_GGS; a_GNN; a_GNS];

   figure; plot(age_xyz(:,1), age_xyz(:,2),'.')

   %% make sure there is no values below zero

   age=age_xyz(:,3);

   for i=1:length(age)
       if age(i) < 0
           age(i)=0;
       else
           age(i)=age(i);
       end
   end

   fid1=fopen('age_mixed.xyz', 'w');
   for i=1:length(age)
       fprintf(fid1, '%f %f %f\n',age_xyz(i,1), age_xyz(i,2), age(i)');
   end

   %% run in GMT - change region if needed

   % gmt blockmean age_mixed.xyz -I1m -R-102.02/-98.44/1.40/3.20 | surface -
I1m -T.3 -Gmod_age.grd -R-102.02/-98.44/1.40/3.20
   % gmt grd2xyz mod_age.grd > mod_age.xyz
```

Matlab Code – to compute 3-dimensional lithospheric thermal structure

```
%% Computing thermal structure of the lithosphere
% Gabriella Alodia
% Modified May 2018
% This code models the thermal structure of the lithosphere using GDH1 'Plate
Model'
% Calculation stops at 95 km
% Mantle Temperature: 1300 C
%%

close all;
clear all;
clc;

%% load age data

age_sorted=load('mod_age.xyz');

lon=age_sorted(:,1);
lat=age_sorted(:,2);
age=age_sorted(:,3);    % age in m.a.

%% make sure there is no age below zero

for i=1:length(age)
    if age(i) < 0
        age(i)=0;
    else
        age(i)=age(i);
    end
end
%% parameters

km=1e3;             % m to km
K=1e-6;             % Kappa
Tm=1300;            % mantle temp (C)

Ma=1e6*365*24*60*60;% m.y. to s

zmax=95;            % in km
z=(0:1:zmax)*km;    % sampled z every 1 km
age_Ma=age*Ma;      % ages in s

yL0=95*km;          % plate thickness in km
                    % using GDH1: 95 km max depth of lithosphere

%% Gridding lon, lat, age

l=length(find(lat==lat(1)));
lon_rs=reshape(lon,l,[]);
lat_rs=reshape(lat,l,[]);
age_rs=reshape(age,l,[]);

figure()
pcolor(lon_rs,lat_rs,age_rs); shading interp
title ('Age of Lithosphere')

%% Calculating T
```

```
dep=9;                    % depth from surface (km)
pos=yL0-dep;              % position calculated (km)

a=2*sqrt(K*age_Ma);

for j=1:length(age)
    for k=1:length(z)
        T(j,k)=Tm*(1+erf((yL0-z(k))./a(j))- erf((yL0+z(k))./a(j)) + ...
        erf((3*yL0-z(k))./a(j)) - erf((3*yL0+z(k))./a(j)) + ...
        erf((5*yL0-z(k))./a(j)) - erf((5*yL0+z(k))./a(j)) + ...
        erf((7*yL0-z(k))./a(j)) - erf((7*yL0+z(k))./a(j)) + ...
        erf((9*yL0-z(k))./a(j)) - erf((9*yL0+z(k))./a(j)) + ...
        erf((11*yL0-z(k))./a(j))- erf((11*yL0+z(k))./a(j)) + ...
        erf((13*yL0-z(k))./a(j)) - erf((13*yL0+z(k))./a(j)) + ...
        erf((15*yL0-z(k))./a(j)) - erf((15*yL0+z(k))./a(j)) + ...
        erf((17*yL0-z(k))./a(j)) - erf((17*yL0+z(k))./a(j)) + ...
        erf((19*yL0-z(k))./a(j)) - erf((19*yL0+z(k))./a(j)) );
    end
end

for i=1:length(age)
   fT(i)=mean(T(i,:));
end

dlmwrite('mod_thermal.xyz',T','delimiter','\t','precision',8);
```

Matlab Code – to compute gravity effect from the thermal model

```
   %% Computing thermal gravity of the lithosphere
   % Gabriella Alod%% Computing thermal gravity of the lithosphere
   % Gabriella Alodia
   % Modified May 2018
   % This code computes the thermal gravity from the thermal lithosphere
created from 'thermal_structure.m' and ASCII age model
   %%

   close all
   clear all
   clc

   %% load T and age data

   T=load('mod_thermal.xyz');
   age_sorted=load('mod_age.xyz');

   lon=age_sorted(:,1);
   lat=age_sorted(:,2);
   age=age_sorted(:,3);    % age in m.a.

   %% parameters

   km=1e3;              % m to km
   K=1e-6;              % kappa
   Tm=1300;             % mantle temp (C)
```

```
Ma=1e6*365*24*60*60;% m.y. to s
zmax=95;            % in km
z=(0:1:zmax)*km;    % sampled z every 1 km
age_Ma=age*Ma;      % ages in s

yL0=95*km;          % plate thickness in km
                    % GDH1: 95 km

%% gravity attraction

alf=3.28*1e-5;      % vol coef of therm exp: degC-1
ro_m=3.33-2.80;      % mantle-crust density contrast

dT_layers=[];

for i=1:length(z)
    for j=1:length(age)
        dT_layers(i,j)=T(i,j)-Tm*(length(z)-(z(i)/km))/yL0;
    end
end

dT_0=dT_layers(96,:);

% gravity in layers

grav=[];

for i=1:length(z)
    for j=1:length(age)
        grav(i,j)=dT_layers(i,j).*-alf*ro_m*100; %scaling factor to mgals
    end
end

grav_tot02=[];

for j=1:length(age)
    grav_tot02(j)=sum(grav(:,j));
end

grav_tot02=grav_tot02;

%% gridding layers

l=length(find(lat==lat(1)));
lon_rs=reshape(lon,l,[]);
lat_rs=reshape(lat,l,[]);
dT_rs=reshape(dT_0,l,[]);
grav_tot02_rs=reshape(grav_tot02,l,[]);

figure()
pcolor(lon_rs,lat_rs,grav_tot02_rs); shading interp

gravtot02_rs=reshape(grav_tot02,l,[]);

figure()
pcolor(lon_rs,lat_rs,gravtot02_rs); shading interp
```

```
   %%  write out file

   dlmwrite('mod_litho.xyz',[lon lat
grav_tot02'],'delimiter','\t','precision',8);

   %% run in GMT - change region if needed

   % gmt blockmean mod_litho.xyz -I1m -R-102.02/-98.44/1.40/3.20 | surface -
I1m -T.3 -Gmod_litho.grd -R-102.02/-98.44/1.40/3.20
   % gmt grdmath mod_litho.grd UPPER = mod_litho_max.grd
   % gmt grdmath mod_litho.grd mod_litho_max.grd SUB = mod_litho_norm.grd
```

5. Calculate BA, MBA, RMBA, and RCT

Using the gridded bathymetry, FAA, and thermal anomaly, we can then compute BA, MBA, and RMBA in GMT. The resulting RMBA is then cosine tapered for 25-35 km in GMT before we calculate the gravity effect using the infinite slab formula in Matlab.

Input: Gridded bathymetry (Grid_all_15May.grd) , FAA (surv_faa_padded.grd), thermal anomaly (mod_litho_norm.grd)
Output: BA (surv_bouguer.grd), MBA (surv_mba.grd), RMBA (surv_rmba.grd), and RCT (surv_rct_25_35_masked.grd)

GMT Code – to compute BA, MBA, RMBA:

```
   set region=-R-102.02/-98.44/1.40/3.20
   set scale=-JM24

   rem downsample bathymetry

   set bathy=Grid_all_15May.grd

   rem gmt grd2xyz %bathy% > bathy.xyz
   rem gmt blockmean bathy.xyz -I1m %region% | surface -I1m -T.3 -
Gsurv_bath_surface.grd %region%

   rem load and write files

   set file1=surv_bath_surface.grd
   set file2=surv_faa_padded.grd
   set file3=surv_water.grd
   set file4=surv_bouguer.grd
   set file5=surv_moho.grd
   set file6=surv_mba.grd
   set file7=mod_litho_norm.grd
   set file8=surv_rmba.grd
   set file9=mean.grd
   set file10=surv_rmba_mean.grd
   set file11=surv_rmba_cosine.grd
   set file12=surv_rmba_cosine.xyz

   rem calculate bouguer anomaly
```

```
gmt gravfft %file1% -D1773 -E4 -V -Gsurv_water.grd
gmt grdmath %file2% %file3% SUB = %file4%

rem calculate MBA

gmt gravfft %file1%=nf/1/-6000 -D530 -Gsurv_moho.grd
gmt grdmath %file4% %file5% SUB = %file6%

rem calculate RMBA

gmt grdmath %file6% %file7% SUB = %file8%

rem remove background anomaly

gmt grdmath %file8% MEAN = %file9%
gmt grdmath %file8% %file9% SUB = %file10%

rem compute RCT
rem grdfft can't compute NaN!

gmt grdfft %file10% -F-/-/35000/25000 -fg -C-10000 -Gsurv_rmba_cosine.grd
gmt grd2xyz %file11% > %file12%
```

Matlab Code – to compute RCT:

```
close all;
clear all;
clc;

%% load data

load surv_rmba_cosine.xyz

lon=surv_rmba_cosine(:,1);
lat=surv_rmba_cosine(:,2);
rmba=surv_rmba_cosine(:,3);

%% load parameters

G=6.673e-11;
rho=660;

for i=1:length(rmba)
    h(i)=((rmba(i).*1e-5)/(2*pi*G*rho))/-1000;
end

fid1=fopen('surv_rct.xyz', 'w');
for i=1:length(lon)
    fprintf(fid1, '%f %f %f\n',lon(i), lat(i), h(i));
end
```

GMT Code – to plot RCT:

```
rem GMT script for plotting gridded files

set ps=surv_rct.ps
```

```
set region=-R-102.02/-98.44/1.40/3.20
set scale=-JM24

rem convert RCT to grd

gmt xyz2grd surv_rct.xyz -R-102.02/-98.44/1.40/3.20 -Gsurv_rct_25_35.grd -I1m

rem load intended grd, mask, and bathymetry (for contour)

set file1=surv_rct_25_35.grd
set file2=surv_mask.grd
set file3=surv_rct_25_35_masked.grd
set bathy=Grid_all_15May.grd

rem load survey track if needed

rem set track=surv_faa_tracks_mixed.xy

rem make colorbar

gmt makecpt -Chaxby -T-4.5/4.5/0.1 > g.cpt

rem mask grid

gmt grdmath %file1% %file2% SUB = %file3%

rem plot grid

gmt grdimage %region% %file3% %scale% -Cg.cpt -K > %ps%
gmt grdcontour %bathy% %scale% %region% -C250 -A1000+f10p -O -K >> %ps%

rem add seismicity and focal mechanism if needed

rem gmt psxy %region% %scale% ISC_Earthquake_Coordinates.txt -W -St0.15c -
Gred -O -K >> %ps%
rem gmt psmeca %region% %scale% GCMT_psmeca_nolabel.txt -Sm0.35c -Gblack -W -
T0 -O -K >> %ps%

rem build data frame and scale bar

gmt pscoast %region% %scale% -Bg.5 -B.5 -BWeSn+t"RCT from 6 km" -W0.5p -O -K
-Lx22/13.5/+c2+w50k+l >> %ps%

rem build color bar

gmt psscale -D12/16/20/0.5h -O -Cg.cpt -B1/:km: -K >> %ps%

rem add survey tracks if needed

rem gmt psxy %track% %region% %scale% -Sc0.03c -Gwhite -O -K >> %ps%
```

Appendix D: ArcGIS

We created a database in ArcGIS using the bathymetry, magnetic, gravity, dredge location and sample description data. The database will be useful for further analysis and study. All the data is georeferenced by the Mercator Projected Coordinated System.

We created attribute tables using the information from the dredges (Lat, Lon, depth, rock type, Dredge ID…). For a dredge line's shape, we used the on-bottom and off-bottom coordinates.

After getting the dredge lines and bathymetry data, we can recognize geological structures and try to understand how they moved to their actual state by making polygons and trying to see their symmetry along the ridge.

By comparing this with the magnetic data, we will able to know how the Cocos-Nazca spreading center and its segments behave.
By the conversion tools from ArcGIS, we can save the bathymetry in ascii format so we can use it in Fledermaus for a 3D View. The shape files can be opened in ArcGIS QGIS