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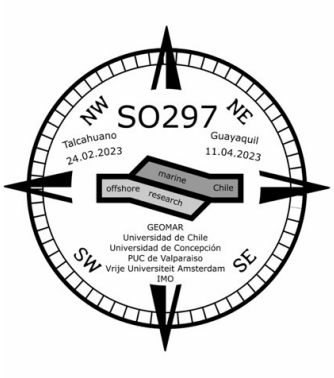

Short Cruise Report

RV SONNE cruise SO297

Talcahuano (Chile) – Guayaquil (Ecuador)

23.02.2023 – 11.04.2023

Chief Scientist: Dr. Dietrich Lange

Captain: Oliver Meyer

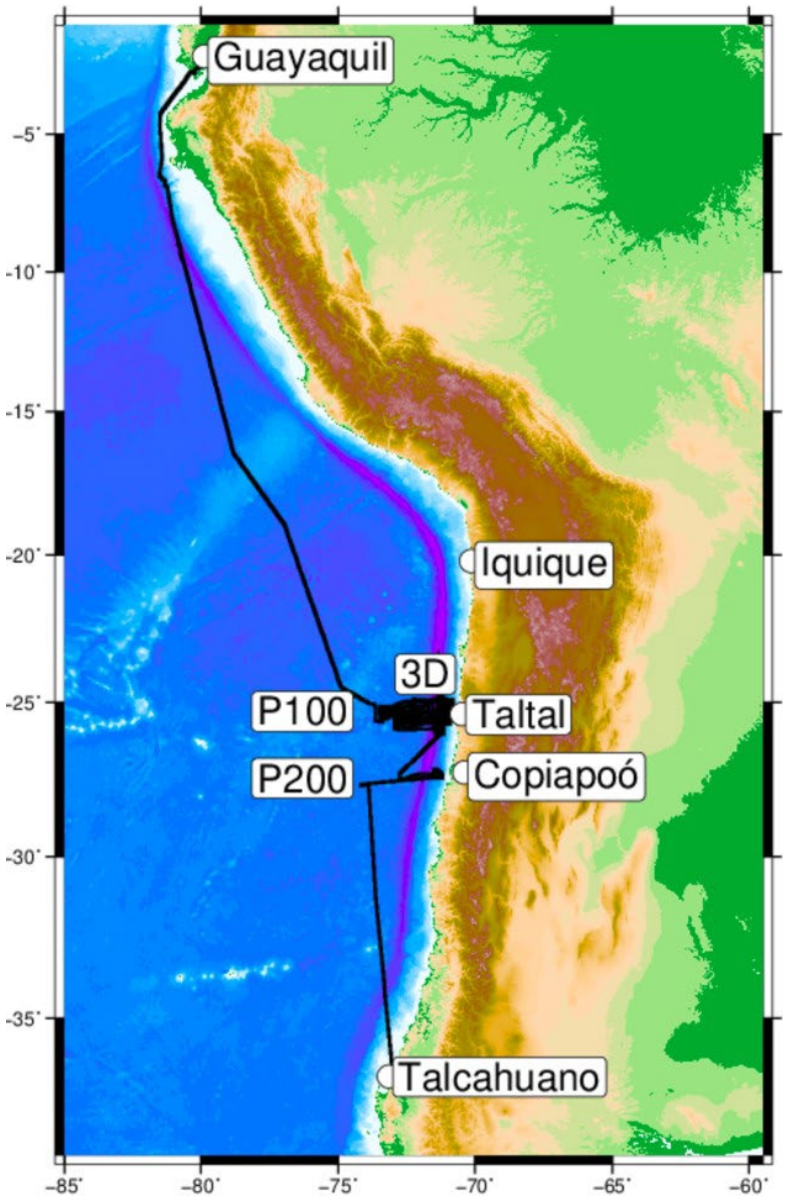

Fig. 1: Cruise rack and stations of RV SONNE cruise SO297.

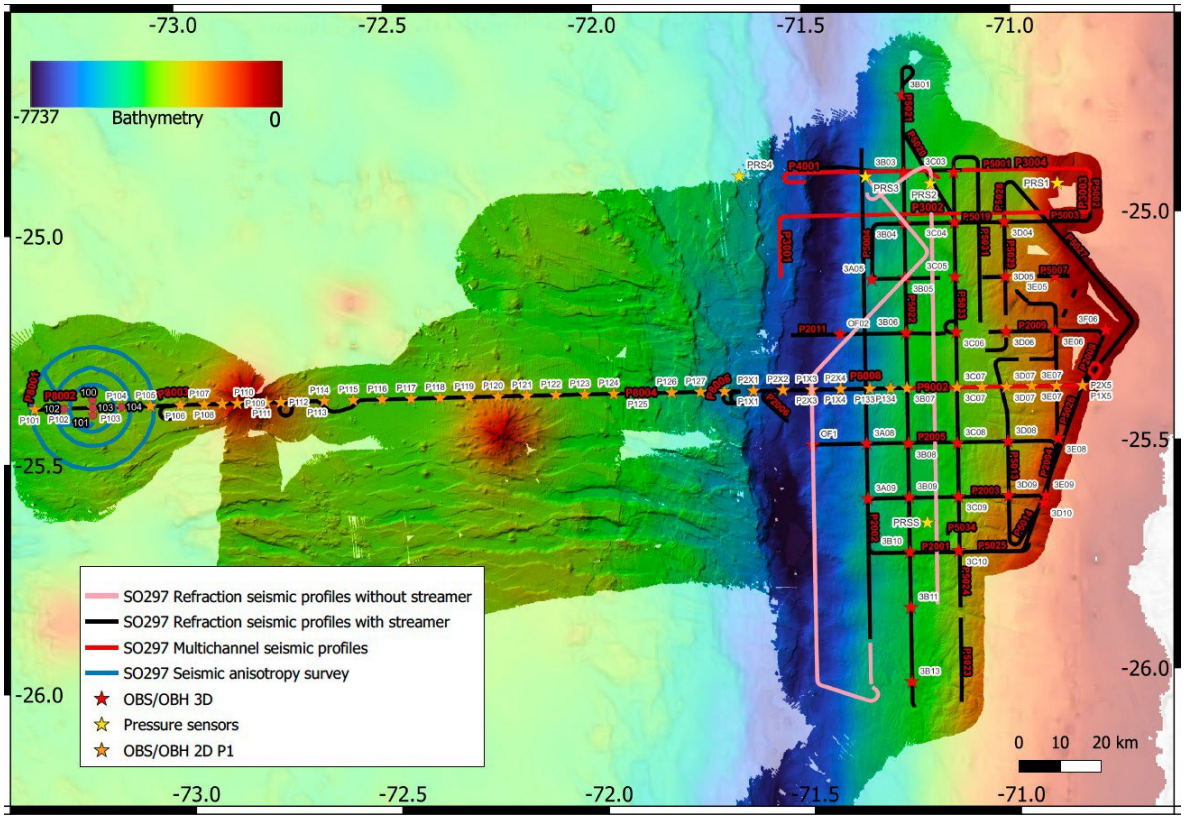

Fig. 2: Overview map of the northern survey area of SO297.

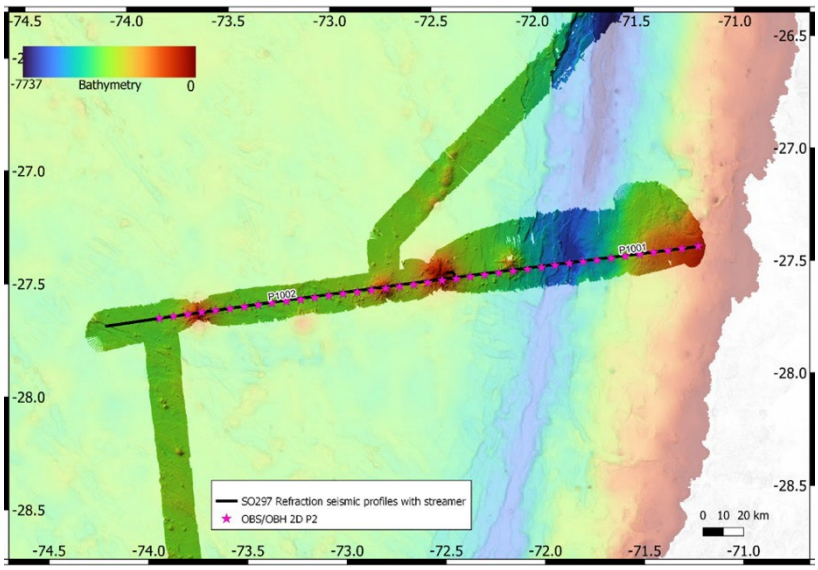

Fig. 3: Overview map of the seismic profile P200 acquired during SO297 in the southern survey area.

Objectives

The objective of cruise SO297 is to investigate in detail the deep structure offshore Taltal and Copiapó with 2D and 3D refraction experiments to analyze the relationship between deformation behavior and forearc structures using the northern Chilean subduction zone as a type location. This work will contribute to regional hazard studies. For a better understanding of the processes, the required knowledge of the deep structure of the marine forearc and the seismogenic zone is lacking to date since this seaward region has not been investigated with modern technology. Therefore, for the first time, the SO297 high-resolution dataset for the marine forearc in Northern Chile will image the forearc of the erosional subduction zone offshore Taltal and Copiapó.

The main theme is the relation of forearc structures on the forearc deformation of an erosive margin during the inter-seismic phase, including its along strike and downdip segmentation in a region where dense geophysical datasets from land observations are available. Associated with this theme are:

a.) the seismotectonic setting of the study area,
b.) the velocity structure of the forearc, including the structure of the oceanic plate,
c.) the internal structure of the forearc for both down-dip and lateral changes,
d.) the structural control on megathrust deformation during the seismic cycle's co-seismic, inter-seismic, and post-seismic phases.

By comparing slip models from geodetic and seismological data (e.g., co-seismic and afterslip models or inter-seismic coupling information) with wide-angle refraction results can resolve a.) and b.) may be resolved. Additionally, the offshore data will be complemented by land observations of the IPOC (Integrated Plate Boundary Observatory Chile) network, the ANILLO project and permanent stations from the Centro Sismológico National (CSN).

Overall, the datasets acquired during SO297 will be used to contribute to the following three hypotheses:

Hypothesis 1: The structural properties of the upper plate determine the upper (seaward) boundary of the seismogenic zone and, thus the rupture size of tsunamigenic earthquakes (e.g. Sallarès and Ranero, 2019).

Hypothesis 2: The coupling properties perpendicular as well as parallel to the deep-sea trench are determined by areas that differ in their frictional properties. The geometry of these rupture regions (asperities) can be mapped by high-resolution refraction-seismic imaging methods and is also likely to be determined by velocity contrasts in the oceanic plate.

Hypothesis 3: The high seismic coupling and associated segmentation of the marine subduction zone have been associated with structural and geometric heterogeneities. Such heterogeneities are caused e.g., by subducted seamount chains or deep-sea mountains and can be identified with wide-angle refraction methods.

Narrative

The purpose of the cruise was to acquire refraction seismic data offshore North-Central Chile focusing on the region of the incoming oceanic plate and marine forearc at latitudes of the Taltal and Copiapó ridge. In general, this region was only sparsely mapped with modern multibeam. Furthermore, we installed five absolute pressure sensors.

After leaving the harbor of Talcahuano/San Vincente, we arrived at the Copiapó ridge (~26.5°S) on 27th February 2023, where we acquired seismic refraction data together with multibeam data along profile P200 until 5th March. We began deploying stations on P200 at a station spacing of 3.8 nautical miles on 27 February. After deploying 29 stations, a CTD was run at 14:00 to obtain a water sound velocity profile. The deployment of the stations continued until 02:00 on 28 February. At one station the floating line got caught under the OBS. This unit was immediately released, a new anchor attached, and was reinstalled after a short time. In the morning of the 28 February RV SONNE mapped the marine forearc with multibeam bathymetry and in the afternoon, the air pulsers and MCS streamer were launched, and marine mammal mitigation measures were started. Throughout the cruise, marine mammal mitigation procedures were followed prior to and during the shooting. The successful recovery of all but one of the seismic stations was completed by the evening of 04 March. On the night of 5 March, we returned to OBH P217 and charted previously unmapped seabed during the transit. We reached the installation position but could not receive any visual or acoustic signals from the station and unfortunately had to leave this station site without OBH P217.

After a short transit to the North, we reached the region of a 3D refraction experiment where we installed 42 OBS/OBH stations covering an area of 60x90 nm. The area was various times mapped with multibeam during the installation and shooting of the refraction experiment, which lasted until 20 March. During this period, we also installed three novel drift-free pressure sensors between March 17- and 21. The installation of the drift-free pressure sensor PRS1 from IMO in 1774 m water depth started after a CTD to obtain a water velocity sound profile. First, an acoustic modem was lowered to 50 m water depth. Then, the pressure sensor PRS1 was lowered on the deep-sea wire to the seafloor. After releasing the instrument, it turned out that it was still attached to the cable, as the depth of the instrument decreased when the cable was uplifted. We hoisted the pressure sensor with its frame to the sea surface. When the instrument reached the sea surface, we saw that the lines were jammed in the device, but the releaser had been triggered. As it was hoisted above the water surface, the weight of the pressure sensor was sufficient to release the lines. The device returned to the seabed with a fall speed of 1 m/s. During its descent, we were connected to the device and could measure the distance and check the status of the device via an acoustic connection at any time. By 13:07 am, it had arrived at 1785 m water depth, standing almost horizontally with an angle of incidence of two degrees. An upload of the data from the device on the seabed showed that the pressure sensor was working as desired. The installation of the other pressure sensors worked without further problems.

We dismantled 12 OBS/OBH stations overnight and installed five new instruments for the second profile (P100) of the cruise at noon on 22 March (Fig. 5.3.12). The subsequent dismantling of another eight stations went smoothly. At 23:00, we reached OBH 3D10, where we were able to measure the acoustic range but could not release the instrument.

On 23 March, we began the installation of 27 new OBS/OBH stations from east to west along profile P1. Around noon we interrupted the station deployment for 3 hours. During this

time, a releaser test was carried out at 2000 m depth. Then, a floating test of a GEOMAR pressure sensor was carried out. Profile P100 was completely installed at 02:00 on 24th March, and we continued with multibeam mapping until 08:00, which revealed some small seamounts and a complex structure of intersecting graben structures. At 08:00 on 25 March, the air pulsers and MCS streamer were deployed again, and FS SONNE started to acquire refraction data along profile P100 and towards the east. At the western end of the profile, the ship turned west to record ~30 miles of MCS data. On 26 March, the dismantling of OBS/OBH along profile P1, starting with P134, commenced, and FS SONNE headed west. The profile and a small anisotropy experiment were successfully acquired, and all OBS/OBH were dissembled by 30th March 2022.

The remaining days until 2nd April at 23:59 were devoted to the installation and visit of pressure sensors, and we mapped uncharted regions in various locations, particularly during the nights.

On 31 March and 1 April, the two pressure sensors from GEOMAR were installed during the daylight at 5400 m and 4650 m water depth, respectively. As with the IMO stations, a pressure sensor from Sonardyne is used. This was mounted on a modified GEOMAR OBS frame with a concrete anchor (Fig. 11.6). However, at the first station, we first encountered a strongly dipping seafloor, and the inclinometer showed a tilt of 22°. The instrument was then hoisted 50 meters and moved 150 meters to the North by ship. One hour later, the instrument was horizontal and fully functional on the seafloor.

On the evening of 01 April 2023, we went to the deployment position of OBH 3D10, which had responded but was not released during dismantling the 3D experiment on 22 March. Automatic time release was set for 02 April at 04:30 UTC or 00:30 shipboard time. 3D10 did not automatically ascend with the time release. On 2 April 2023, we tried to recover the OBH 3D10 from the seafloor by dredging but could not get the stations up from 1900 m water depth.

Between 2nd April and 4th April at 23:59 April RV SONNE headed towards Guayaquil and mapped continuously uncharted seafloor. We left our working area on April 4 at 23:59 and headed toward the port of Guayaquil, where RV SONNE safely arrived on April 11, 2023, terminating cruise SO297.

Acknowledgements

The ambitious planning and preparation related to cruise SO297 of RV SONNE would not have been possible without the excellent shore-based administrative and logistical support of the Leitstelle Deutsche Forschungsschiffe, Briese Research and the Projektträger Jülich. We gratefully acknowledge the help of the Foreign Office in Berlin and the German Embassy in Santiago de Chile. We would also like to thank the Government of Chile for granting the opportunity to work within their territorial waters. S.H.O.A. is thanked for the efficient permitting process. We especially thank Captain Oliver Meyer and his crew for their skillful execution of the complex scientific program and the pleasant atmosphere on board. The cruise and scientific work were financed by the Bundesministerium für Bildung und Forschung (BMBF) under grant 03G0297A (PISAGUA) with additional funding and use of large-scale equipment from GEOMAR.

Participants List

Name	Discipline	Institution
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Warwel, Arne	OBH/OBS	GEOMAR
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Station Lists

Table 1: List of CTD stations.

Station No.	Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/Recovery
SONNE	2023		[UTC]	[°N]	[°W]	[m]	
SO297_3	26.02.	CTD	04:34	30°59.90'	73°39.76'	2500	Deployed/Recovered
SO297_27-1	27.02.	CTD	19:06	27°31.85'	72°11.41'	2500	Deployed/Recovered
SO297_91-2	06.03.	CTD	12:27	25°22.76'	71°25,17'	2500	Deployed/Recovered
SO297_130-1	17.03.	CTD	09:22	24°56.20'	70°53,50'	1700	Deployed/Recovered

Table 2: List of absolute pressure sensor deployments. The long-term deployments are planned to remain five years (IMO instruments) and two years (GEOMAR instruments) on the seafloor.

Station No.	Date	Gear	Time	Latitude	Longitude	Water Depth	Remarks/Recovery
SONNE	2023		[UTC]	[°N]	[°W]	[m]	
SO297_133-1	19.03.	PRS3	17:41	24°55.00'	71°21.10’	5961.0	Deployed, IMO, 1902
SO297_131-1	17.03.	PRS1	16:38	24°56.20’	70°53.49’	1785.0	Deployed, IMO, 1903
SO297_147-1	21.03.	PRS2	12:16	24°56.00’	71°11.80’	4449.0	Deployed, IMO, 1901
SO297_250-1	31.03.	PRS4	16:32	24°55.90’	71°38.73’	5480.0	Deployed, GEOMAR, 1905
SO297_251-1	01.04.	PRSS	15:46	25°40.50’	71°13.01’	4598.0	Deployed, GEOMAR, 1904

Table 3: List of installed OBS/OBH. Station coordinates correspond to the deployment coordinates of DSHIP.

Station No.	Date	Gear	Time	Latitude	Longitude	Water Depth	Name/
	2023		[UTC]	[°N]	[°W]	[m]	Remarks
SO297_2-1	27.02.	OBS	03:47	27°40.86'	73°53.81'	4330.6	P201
SO297_3-1	27.02.	OBS	04:34	27°40.47'	73°49.55'	3933.3	P202
SO297_4-1	27.02.	OBS	05:21	27°40.12'	73°45.22'	3045.5	P203
SO297_5-1	27.02.	OBH	06:02	27°39.77'	73°41.08'	1952.2	P204
SO297_6-1	27.02.	OBS	06:47	27°39.39'	73°36.87'	3560.6	P205
SO297_7-1	27.02.	OBS	07:31	27°39.04'	73°32.56'	4199.3	P206
SO297_8-1	27.02.	OBS	08:11	27°38.68'	73°28.31'	4126.5	P207
SO297_9-1	27.02.	OBS	08:43	27°38.30'	73°24.03'	4400.7	P208
SO297_10-1	27.02.	OBS	09:14	27°37.95'	73°19.80'	4126.1	P209
SO297_11-1	27.02.	OBS	09:45	27°37.59'	73°15.56'	4176.8	P210
SO297_12-1	27.02.	OBS	10:17	27°37.26'	73°11.31'	4181.0	P211
SO297_13-1	27.02.	OBS	10:50	27°36.86'	73°07.10'	4202.3	P212
SO297_14-1	27.02.	OBS	11:22	27°36.47'	73°02.83'	4291.6	P213
SO297_15-1	27.02.	OBS	11:52	27°36.10'	72°58.56'	3814.2	P214
SO297_16-1	27.02.	OBS	12:22	27°35.77'	72°54.35'	3778.7	P215
SO297_17-1	27.02.	OBS	12:54	27°35.37'	72°50.08'	3220.7	P216
SO297_18-1	27.02.	OBH	13:23	27°35.00'	72°45.83'	1711.5	P217 - lost
SO297_19-1	27.02.	OBH	13:56	27°34.62'	72°41.63'	3556.0	P218
SO297_20-1	27.02.	OBH	14:26	27°34.22'	72°37.40'	3178.5	P219
SO297_21-1	27.02.	OBH	14:58	27°33.77'	72°33.21'	2733.4	P220
SO297_22-1	27.02.	OBH	15:27	27°33.37'	72°28.94'	1454.4	P221
SO297_23-1	27.02.	OBH	15:58	27°33.00'	72°24.67'	2928.6	P222
SO297_24-1	27.02.	OBS	16:34	27°32.57'	72°20.48'	3920.1	P223
SO297_25-1	27.02.	OBS	17:09	27°32.16'	72°16.21'	4086.8	P224
SO297_26-1	27.02.	OBS	17:46	27°31.75'	72°11.97'	4347.5	P225
SO297_28-1	27.02.	OBS	20:52	27°31.37'	72°07.68'	4316.1	P226
SO297_29-1	27.02.	OBS	21:33	27°30.95'	72°03.44'	5089.1	P227

SO297_30-1	27.02.	OBS	22:18	27°30.53'	71°59.08'	5718.9	P228
SO297_31-1	27.02.	OBS	22:56	27°30.17'	71°54.94'	6211.6	P229
SO297_31-1	27.02.	OBS	23:35	27°30.14'	71°55.01'	6109.2	P229
SO297_32-1	28.02.	OBS	00:18	27°29.65'	71°50.77'	7011.9	P230
SO297_33-1	28.02.	OBS	00:55	27°29.32'	71°46.54'	6095.9	P231
SO297_34-1	28.02.	OBS	01:38	27°28.96'	71°42.33'	5716.0	P232
SO297_35-1	28.02.	OBS	02:16	27°28.53'	71°38.08'	5179.4	P233
SO297_36-1	28.02.	OBS	02:55	27°28.09'	71°33.85'	5069.2	P234
SO297_37-1	28.02.	OBH	03:34	27°27.64'	71°29.61'	3111.8	P235
SO297_38-1	28.02.	OBH	04:15	27°27.19'	71°25.44'	2558.6	P236
SO297_39-1	28.02.	OBH	05:00	27°26.78'	71°21.20'	2451.7	P237
SO297_40-1	28.02.	OBH	05:44	27°26.32'	71°17.01'	2019.1	P238
SO297_41-1	28.02.	OBS	06:31	27°25.80'	71°12.07'	1675.9	P239
SO297_83-1	06.03.	OBS	03:33	26°01.37'	71°15.62'	4617.1	3B13
SO297_84-1	06.03.	OBS	04:48	25°51.60'	71°15.60'	5237.1	3B11
SO297_85-1	06.03.	OBS	06:36	25°37.24'	71°21.55'	7132.2	3A09
SO297_86-1	06.03.	OBS	07:32	25°30.02'	71°21.61'	5801.3	3A08
SO297_87-1	06.03.	OBS	08:25	25°30.00'	71°29.41'	7143.2	OF01
SO297_88-1	06.03.	OBS	09:37	25°22.78'	71°37.82'	6262.5	P2X1
SO297_89-1	06.03.	OBS	10:09	25°22.77'	71°33.55'	7196.2	P2X2
SO297_90-1	06.03.	OBS	10:38	25°22.79'	71°29.39'	7309.5	P2X3
SO297_91-1	06.03.	OBS	11:08	25°22.77'	71°25.21'	6515.4	P2X4
SO297_92-1	06.03.	OBS	15:09	25°22.80'	71°15.64'	4900.3	3B07
SO297_93-1	06.03.	OBS	16:06	25°15.55'	71°15.65'	5450.3	3B06
SO297_94-1	06.03.	OBS	17:11	25°15.58'	71°25.19'	6837.6	OF02
SO297_95-1	06.03.	OBS	18:17	25°08.47'	71°20.44'	7805.0	3A05
SO297_96-1	06.03.	OBS	18:58	25°08.36'	71°15.62'	7357.9	3B05
SO297_97-1	06.03.	OBS	19:52	25°01.22'	71°15.60'	7677.1	3B04
SO297_98-1	06.03.	OBS	20:36	24°54.59'	71°15.59'	7658.0	3B03
SO297_99-1	06.03.	OBS	21:48	24°44.39'	71°15.64'	5246.8	3B01
SO297_100-1	06.03.	OBS	23:13	24°54.59'	71°08.40'	4213.4	3C03
SO297_101-1	07.03.	OBS	00:04	25°01.15'	71°08.38'	4066.1	3C04
SO297_102-1	07.03.	OBH	01:01	25°01.19'	71°01.21'	3364.8	3D04
SO297_103-1	07.03.	OBH	02:04	25°08.38'	71°01.16'	3121.7	3D05
SO297_104-1	07.03.	OBH	03:01	25°08.40'	70°54.00'	2367.9	3E05
SO297_105-1	07.03.	OBH	04:22	25°15.56'	70°46.80'	1648.8	3F06
SO297_106-1	07.03.	OBH	05:36	25°15.61'	70°54.08'	2278.3	3E06
SO297_107-1	07.03.	OBH	06:31	25°15.59'	71°01.21'	3109.4	3D06
SO297_108-1	07.03.	OBS	07:54	25°08.31'	71°08.44'	4323.6	3C05
SO297_109-1	07.03.	OBS	08:57	25°15.59'	71°08.41'	4127.9	3C06
SO297_110-1	07.03.	OBS	09:54	25°22.80'	71°08.39'	4081.6	3C07
SO297_111-1	07.03.	OBS	10:51	25°22.84'	71°01.22'	3544.3	3D07
SO297_112-1	07.03.	OBS	11:48	25°22.82'	70°54.00'	2230.3	3E07
SO297_113-1	07.03.	OBH	12:27	25°22.79'	70°50.25'	1614.2	P1X5
SO297_114-1	07.03.	OBH	13:23	25°29.71'	70°53.85'	2214.9	3E08
SO297_115-1	07.03.	OBH	14:18	25°30.03'	71°01.15'	3598.6	3D08
SO297_116-1	07.03.	OBS	15:07	25°30.14'	71°08.47'	4254.2	3C08
SO297_117-1	07.03.	OBS	15:52	25°30.11'	71°15.57'	4826.1	3B08
SO297_118-1	07.03.	OBS	16:43	25°37.12'	71°15.56'	4861.5	3B09
SO297_119-1	07.03.	OBS	17:35	25°44.32'	71°15.61'	4673.8	3B10
SO297_120-1	07.03.	OBH	18:26	25°44.26'	71°08.53'	3662.6	3C10
SO297_121-1	07.03.	OBS	19:22	25°37.16'	71°08.44'	4178.1	3C09
SO297_122-1	07.03.	OBH	20:11	25°37.18'	71°01.19'	2863.1	3D09
SO297_123-1	07.03.	OBS	20:48	25°37.19'	70°55.78'	2030.3	3E09
SO297_124-1	07.03.	OBS	21:01	25°38.09'	70°56.12'	1904.6	3D10 Lost
SO297_160-1	22.03.	OBS	15:25	25°22.75'	71°21.00'	5821.3	P133

SO297_161-1	22.03.	OBS	15:51	25°22.78'	71°18.05'	5376.8	P134
SO297_162-1	22.03.	OBS	16:35	25°22.79'	71°12.02'	4501.2	P136
SO297_163-1	22.03.	OBS	17:26	25°22.77'	71°04.83'	3956.0	P138
SO297_164-1	22.03.	OBS	18:16	25°22.79'	70°57.61'	3019.7	P140
SO297_173-1	23.03.	OBS	10:53	25°22.78'	71°41.99'	5955.1	P128
SO297_174-1	23.03.	OBS	11:20	25°22.81'	71°45.45'	5386.8	P127
SO297_175-1	23.03.	OBS	11:52	25°22.81'	71°49.64'	5001.0	P126
SO297_176-1	23.03.	OBS	12:26	25°22.78'	71°53.87'	4523.9	P125
SO297_177-1	23.03.	OBS	12:58	25°22.78'	71°57.96'	4283.0	P124
SO297_178-1	23.03.	OBS	13:28	25°22.76'	72°02.20'	4242.9	P123
SO297_179-1	23.03.	OBS	14:04	25°22.82'	72°06.34'	3982.6	P122
SO297_180-1	23.03.	OBH	14:40	25°22.80'	72°10.55'	3348.3	P121
SO297_181-1	23.03.	OBH	15:18	25°22.81'	72°14.72'	3161.5	P120
SO297_182-1	23.03.	OBH	16:05	25°22.79'	72°18.95'	3306.8	P119
SO297_183-1	23.03.	OBS	16:48	25°22.77'	72°23.10'	3990.9	P118
SO297_184-1	23.03.	OBS	17:34	25°22.79'	72°27.30'	4214.6	P117
SO297_185-1	23.03.	OBS	20:09	25°22.80'	72°31.49'	4206.1	P116
SO297_186-1	23.03.	OBS	20:53	25°22.80'	72°35.69'	4107.6	P115
SO297_187-1	23.03.	OBS	21:36	25°22.78'	72°39.84'	3810.2	P114
SO297_188-1	23.03.	OBS	22:14	25°22.78'	72°43.42'	3242.3	P113
SO297_189-1	23.03.	OBS	22:43	25°22.79'	72°46.13'	2592.8	P112
SO297_190-1	23.03.	OBS	23:07	25°22.77'	72°48.22'	1901.9	P111
SO297_191-1	23.03.	OBS	23:37	25°22.78'	72°50.79'	1131.0	P110
SO297_192-1	24.03.	OBS	00:13	25°22.81'	72°52.44'	1414.5	P109
SO297_193-1	24.03.	OBH	00:56	25°22.80'	72°54.54'	2268.4	P108
SO297_194-1	24.03.	OBH	01:44	25°22.82'	72°57.12'	3013.0	P107
SO297_195-1	24.03.	OBH	02:43	25°22.78'	73°00.58'	3597.9	P106
SO297_196-1	24.03.	OBS	03:26	25°22.77'	73°04.88'	3963.0	P105
SO297_197-1	24.03.	OBS	04:11	25°22.79'	73°09.06'	3964.9	P104
SO297_198-1	24.03.	OBS	05:00	25°22.79'	73°13.21'	3807.6	P103
SO297_199-1	24.03.	OBH	05:47	25°22.81'	73°17.42'	4232.5	P102
SO297_231-1	28.03.	OBS	09:31	25°21.75'	73°13.26'	3820.1	P100
SO297_232-1	28.03.	OBS	09:58	25°23.77'	73°13.27'	3830.2	P101