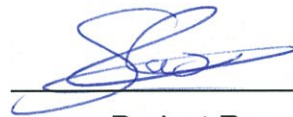
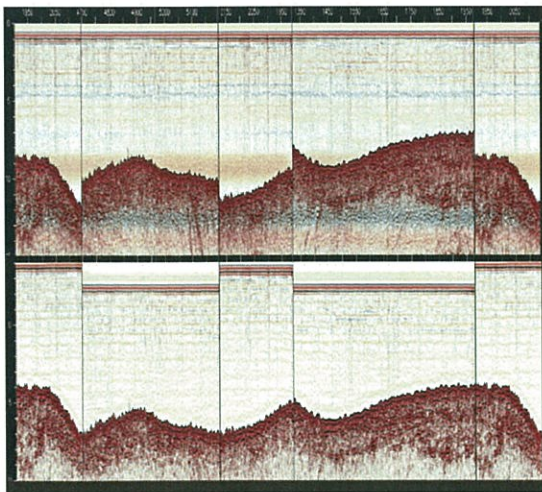


Unidade de Geologia Marinha
Relatório Técnico
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Processing of the Seismic Reflection Data of the SCARPS Cruise Sado Estuary Area (Portugal)

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Project Responsible

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Unidade de Geologia Marinha
Responsible

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1 Introduction

The SCARPS cruise was carried out from the 19th to the 25th of September 2011, under the scope of the project “Reconstruction of the shoreline position along the Portuguese coast over the last 6000 years - Analysis of the architecture and stratigraphy of sand barriers” (SCARPS, PTDC/CTE-GIX/101466/2008). This project, supported by the Fundação para a Ciência e a Tecnologia (FCT, Foundation for Science and Technology), is led by Susana Costas and its being currently developed at the Unidade de Geologia Marinha (UGM, Unit of Marine Geology) of the Laboratório Nacional de Energia e Geologia (LNEG, I.P., National Laboratory of Energy and Geology) since February 2010.

The objective of this cruise was to characterize the subsurface stratigraphic architecture of the nearshore coastal zone along the Tróia peninsula and the Sado estuary ebb-tidal delta. It is expected that this knowledge will permit the correlation of the submerged and the subaerial geological stratigraphy of the coastal lithosome. Subsequently, the grasp of the entire costal lithosome will allow us to better reconstruct the Holocene evolution of this coastal sector.

During the SCARPS cruise were acquired about 260km of single channel high resolution seismic reflection profiles using an IKB-Seistec profiler; a catamaran based sub-bottom seismic system with a boomer source. More information about the SCARPS cruise operation can be found in the technical report INGMARDEP-04-2011 of the LNEG UGM.

This report describes the quality control and processing procedures adopted to process the SCARPS seismic reflection data. The report includes (1) a description of the main characteristics of the seismic data, (2) the major problems of the dataset are identified and enumerated, and finally (3) a processing strategy is delineated that includes 3 main processing phases: 1) navigation processing, 2) tide correction, and 3) seismic signal processing carried out in the Landamrk environment.

1.1 Quality control and signal analysis

1.1.1 Seismic data general information

The seismic signal was saved in two channels: The channel 1 (ch1) saved a pre-processed signal with a time variant gain, while the channel 2 (ch2) saved the raw signal. The ch2 was only saved starting from line 15th onwards.

Main characteristics of the seismic data:

Seismic System: Seistec, Boomer with line-in-cone receiver

Location: Offshore of the Sado estuary, ebb-tide delta and Tróia peninsula shoreface

Shot rate: 3/8 s \approx 0.375s

Estimated mean acquisition velocity: 4 knots, \approx 2m/s

Estimated seismic trace separation: 0.77m, \approx 0.8m

Sampling rate: 51.2KHz, sample interval = 0.01953125ms (in the SEG- Y registered as 19 μ m)

Energy: 150J

Water depth: 2 to 30m

Acquisition geometry: Seistec catamaran towed from the port side at about 1,65m from the boat gunwale and at 2,0m from the boat stern. The GPS antenna was mounted in the Seistec catamaran at mid distance between the source and the receiver.

1.2 Seismic signal analysis

The seismic signal analysis was made using the software RadExPro Plus (version 3.7) from the DECO Geophysical, which will be hereafter shortly referenced as Radex. The frequency spectrum in the water column and sub-bottom areas were examined in both the ch1 and ch2 seismic profiles (Figure 1 and Figure 2). From the observation of the frequency spectrum of several seismic lines, it was concluded that the frequency spectrum has 5 recognizable bands, being the signal essentially concentrated in the band between 1000 and 12000 Hz (Table 1).

Table 1 – Brief analysis of the 5 five identified bands of the seismic signal frequency spectrum.

Band area	Frequency interval (Hz)	Observations
1	0-1000	0-500 only noise 500-1000 essentially noise, very low signal that can be neglected
2	1000-12000	Main seismic signal interval
3	12000-20000	Correspond essentially to noise in the superficial sub-bottom area. Without identifiable contribution to the seismic signal
4	20000-21000	Noise
5	21000-26000	Noise

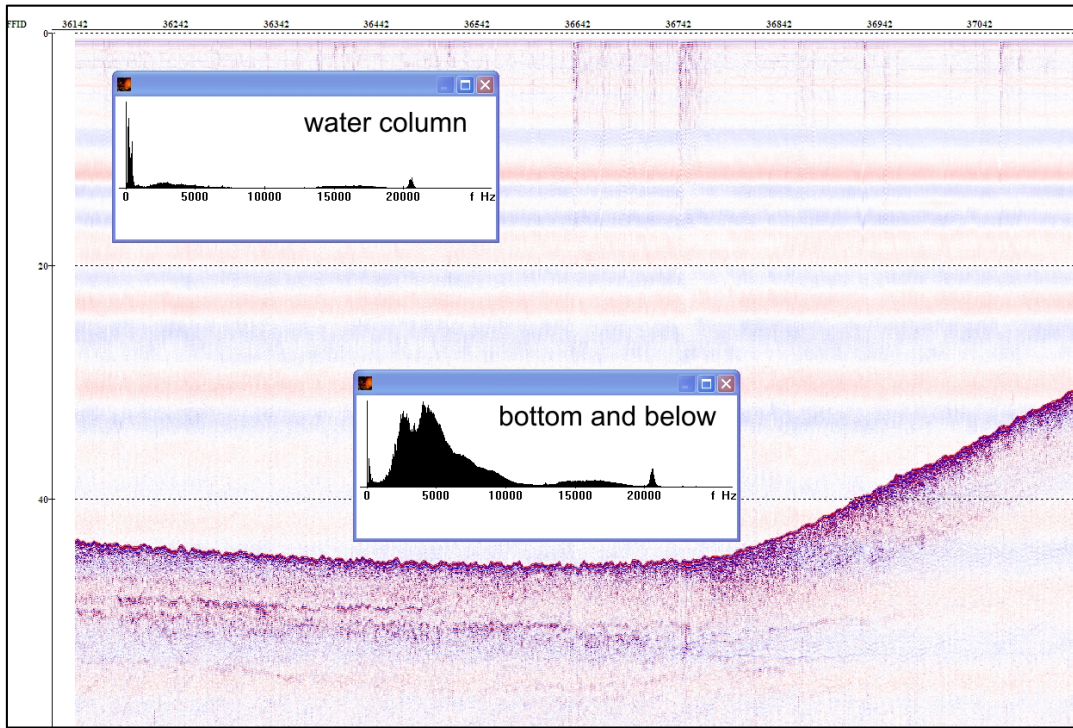


Figure 1 – Example of the signal frequency spectrum for line SCARPS-44 ch1.

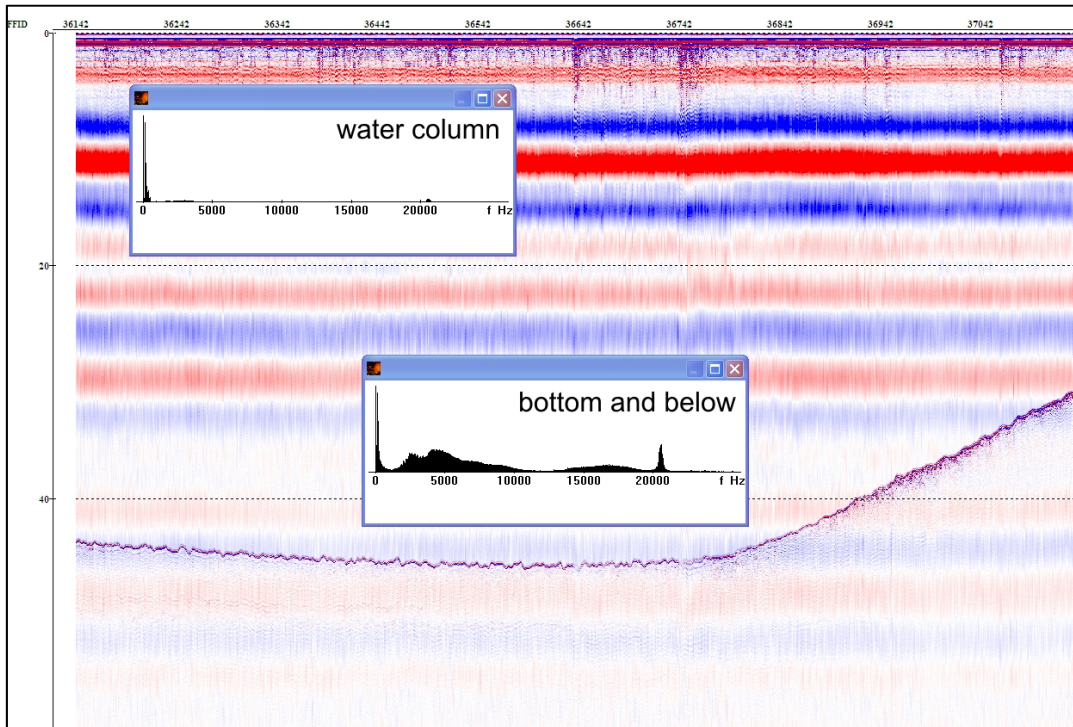


Figure 2 - Example of the observed seismic signal frequency spectrum of the line SCARPS-44 ch2.

1.3 Seismic data identified problems and processing strategy

The major identified problems within the SCARPS seismic dataset were:

1. Biased vertical (time) scale, caused by an incorrect sample rate value stored in the SEG-Y files;
2. Tide induced seismic trace vertical displacement;
3. Unpopulated “trace sequence number within line” (SEQWL, bytes 1-4) field of the SEG-Y trace header files.

In addition to improving the signal to noise ratio of the seismic dataset, the seismic processing strategy should be capable of tackle with a solution for the 3 identified problems. Other requirements for the adopted seismic processing procedures were:

1. The large number of lines (85) of the dataset implies that single line processing procedures could become very time consuming. Thus a multiple line (batch) processing strategy is preferred;
2. To future avoid limitation uploading this dataset into several software for seismic data interpretation, the procedure was also aimed at producing new versions of SEG-Y files incorporating the sample rate and tide corrections.

Several processing procedures were tested using the software Radex and the PostStack Landmark data loader module. It was decided to focus the processing procedures in the PostStack, mainly because of the multiple line (batch) processing possibility of this software.

It was also tested the application of the same processing procedures to channel 1 (ch1) and channel 2 (ch2) lines. Since that no relevant differences were noted and that the raw ch2 lines collection does not include the first two days of data acquisition, it was decided to process only the ch1 seismic lines.

Besides the data resample to correct the sample rate and the trace vertical shift to correct the tide displacement effect, it was decided to apply 3 other processing operations: Band pass filter, dip scan stack and trace mixing, following the processing steps schematized in Figure 3.

1.3.1 Incorrect sample rate

The sample rate of the seismic lines is 0.01953125ms, being this value imposed by the characteristics of the digitalization board used during the acquisition. However, the sample rate recorded into the SEG-Y header files is 19 μ m (0.019ms) because this field of the SEG-Y standard only allows integers of microseconds. The difference between the real and the SEG-Y assumed sample rate is reflected as a bias of the vertical (time) scale of the seismic profiles. Since that this bias is

cumulative, it becomes particularly relevant for higher depths (e.g. in the base of the Sado delta frontal lobe).

In order to minimize the bias imposed by this rounding of the vertical (time) scale of the seismic lines, the sample rate saved in the SEG-Y files was overridden by the value 19,53ms during the importation of the data into the Landmark environment. Subsequently, the time scale of the imported seismic lines was affected by a multiplication factor of 1000. Therefore, the seismic data were resampled into a sample rate of 20ms and afterwards the sample rate was manually edited to 0,02ms (20 μ m), restoring the vertical scale to its real value (considering a rounding into the tenth of microsecond) in a form now compatible with the SEG-Y standards.

The 0.02ms resample rate adopted allows the preservation of seismic signal up to 25000Hz (Nyquist frequency of 50000Hz = $1/0.02*1000$) which according with the observed seismic signal frequency spectrum (Figure 1 and Figure 2) encompasses the entire seismic signal.

1.3.2 Tide imposed vertical displacement

To bring all the seismic lines to the same vertical datum, the vertical shift induced by the tide must be corrected. To evaluate if the tide correction can be made by a single static shift for each line (line static shift) or if it is necessary to use different static corrections in the same line (trace static shift) it was estimated the maximum intra-line tidal shift. The acquisition of the longest line (line 50) took about 50 minutes. Assuming a tidal amplitude of 3.5m and a linear tide height variation along the 6 hours of the tide half-cycle, the 50 minutes that took the acquisition of the longest seismic line, can account for a vertical shift of about 0.5m (≈ 0.66 ms) between the beginning (SOL) and the end (EOL) of the line. Considering that the data sampling interval is of 0.02ms (≈ 1.5 cm), a 0.5m vertical shift is very significant. Thus, a trace static shift should be used to correct the tidal induced vertical shift.

The tidal elevation was determined for each trace and converted to two-way travel time. That time correction was uploaded into the SEG-Y trace header as a delay recording time and was added to the trace time during the data import into the Landmark environment.

1.3.3 Unpopulated SEQWL field of the SEG-Y trace header

The SEQWL field of the SEG-Y trace header files was populated during the procedure used to save the information used to correct the tide induced trace vertical displacement to the SEG-Y headers.

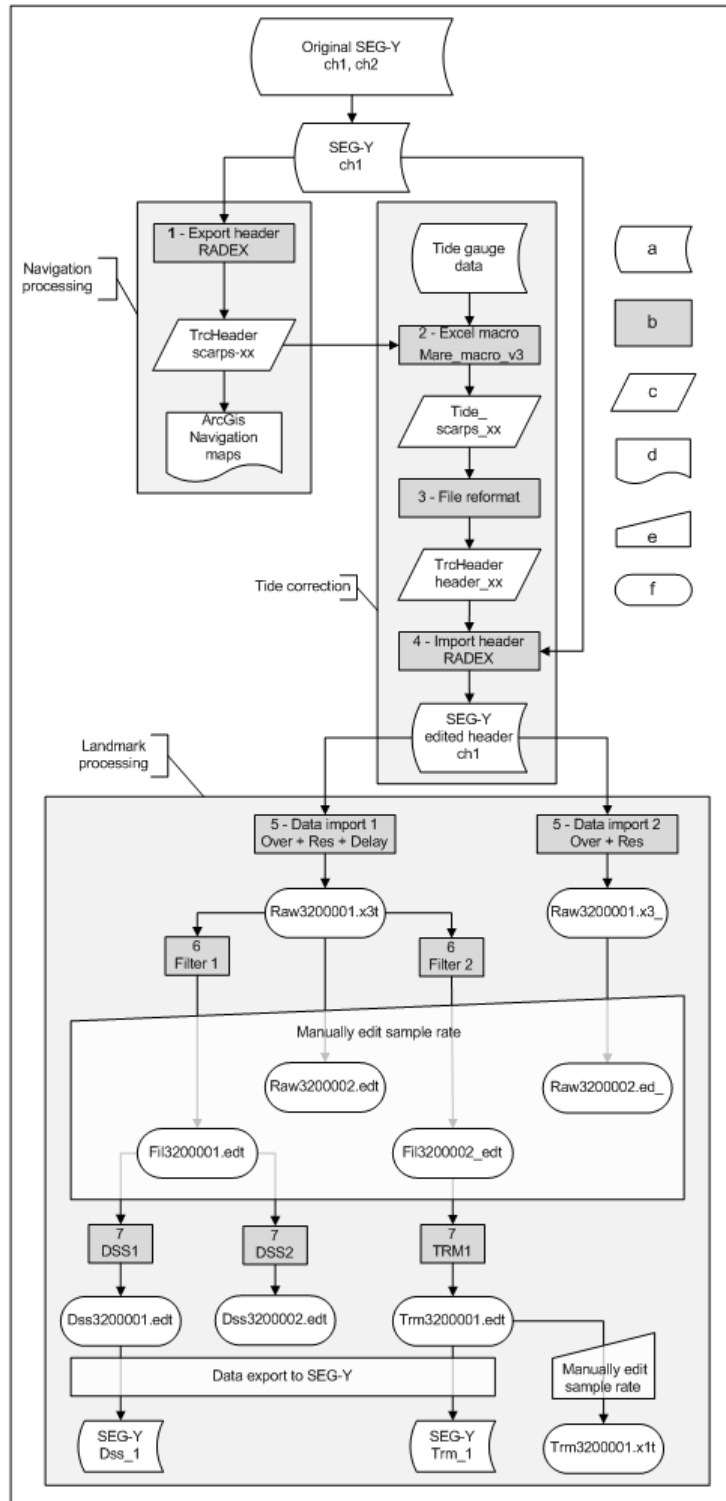


Figure 3 – flow adopted for the processing of the SCARPS seismic reflection data. Flow polygons meaning: a-input/output data, b-processing step/module, c-ASCII file, d-produced document, e-manual process and f-Landmark seismic (vertical) file.

2 Navigation data

During the seismic data acquisition the GPS data was directly saved into the SEG-Y files, both in geographic WGS84 and projected UTM coordinates. Thus, to produce the maps with the acquired seismic profiles location it was necessary to extract from the SEG-Y trace headers the correspondent navigation.

The software SeisSee was used to export the trace headers of the original SEG-Y files of each seismic line into ASCII text files, using the functionality “File/Export trace header to ASCII file”, without checking the option “write column info”. The SEG-Y trace header fields exported were: Trace, FFID, SRCX, SRCY, GRP X, GRP Y, YEAR, DAY, HOUR, MINUTE, SCE (second), TMBS and TWF. The resultant ASCII files were imported to Excel files where a new row with header names and a new column (field) with the seismic line name were added.

The resultant Excel files were used for two purposes: 1) To compile the navigation data and produced the cruise navigation maps using the Esri geographic information system ArcGis (version 10); 2) To import the trace number and respective time stamp to the Excel macro Mare_macro_v3.xls (step 2 of the processing flow, Figure 3).

3 Tide correction procedures

The data used to correct the tidal induced vertical shift of the SCARPS seismic lines corresponded to the tide record measured at the Tróia tide gauge and were provided by the Instituto Hidrográfico (Hydrographic Institute) in a time series with a frequency of one minute (Figure 4).

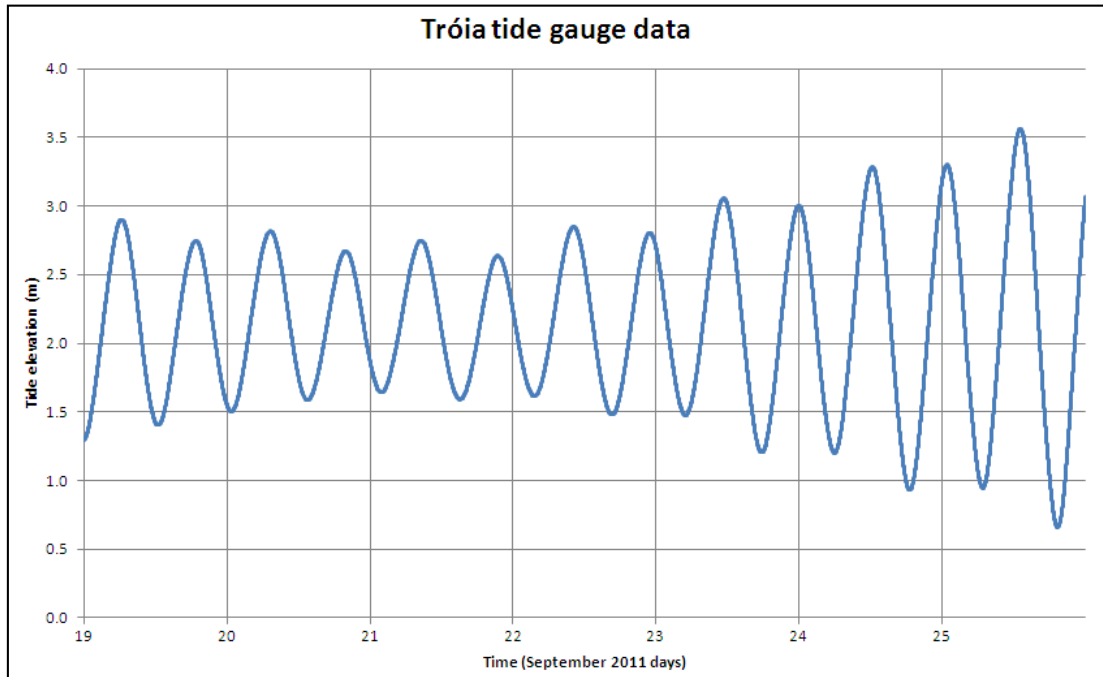


Figure 4 – Tróia tide gauge data used to correct the tidal induced vertical shift of the SCARPS seismic lines.

The process adopted for correcting the tidal shift in the seismic lines included the following 3 steps:

1. Determination of the current tide elevation for each trace, obtained from the correlation of time stamps of the seismic traces and the tidal elevation data, made with an Excel Visual Basic macro (Mare_macro_v3.xls) programmed specifically for that function. Export to ASCII tab delimited text files of the resultant data sets;
2. Reformatting of the ASCII tidal correction data files using gawk;
3. Import to the trace header of the SGE-Y files of the tide correction (and trace number) data.

3.1 Correlation of tidal data and trace number time stamps (Step 2, Figure 3)

A Visual Basic Excel macro (Mare_macro_v3.xls, running in Microsoft Office Excel 2007.) was written specifically to match the time stamps of the tide and seismic trace data sets (annex 35.3). The algorithm implemented to match the time stamps does not include any type of interpolation of the data sets and assumes that the tide data series are sorted from the small to the largest time stamps. For each seismic trace, the algorithm runs the tide data series comparing the time stamp of the seismic trace with the tide data time stamps, until find out the tide record with the lowest time stamp that does not exceed the time stamp of the seismic trace. The seismic trace number and the

correspondent tide elevation data are then written on the results worksheet and the procedure is repeated for the following seismic trace.

The Excel workbook file where the macro was implemented comprises 3 main worksheets: 1) tide data; 2) seismic data and 3) results. The workbook also includes a fourth worksheet where specific notes for each seismic line can be made and where examples of the required data fields and respective formats necessary for the proper work of the macro are displayed.

3.1.1 Tide data worksheet

The tidal data series must be imported into the worksheet “Tide_data” (Figure 5). The implemented algorithm is only prepared to deal with tide data sets collected during the same day. This data series can comprehend four fields (columns) that can be directly pasted into the worksheet. The fields “place” and “date” are used only as reference information. The fields, “time” and “tidal height”, are the ones that will be used in the computations. The time field must be formatted as text in the form HH:MM:SS in order to be converted to the Tide_time field that is the correspondent time tag expressed in seconds. Besides the Tidal Height (TH), which must be expressed in meters, two additional variables are used to calculate the Final Tidal Correction (FTC): 1) the Delay (D) and 2) the Multiplication Factor (MF). The relation between the computed final tidal correction and the tidal height is given by the following formula:

$$FTC = D - TH * 0.75 * MF$$

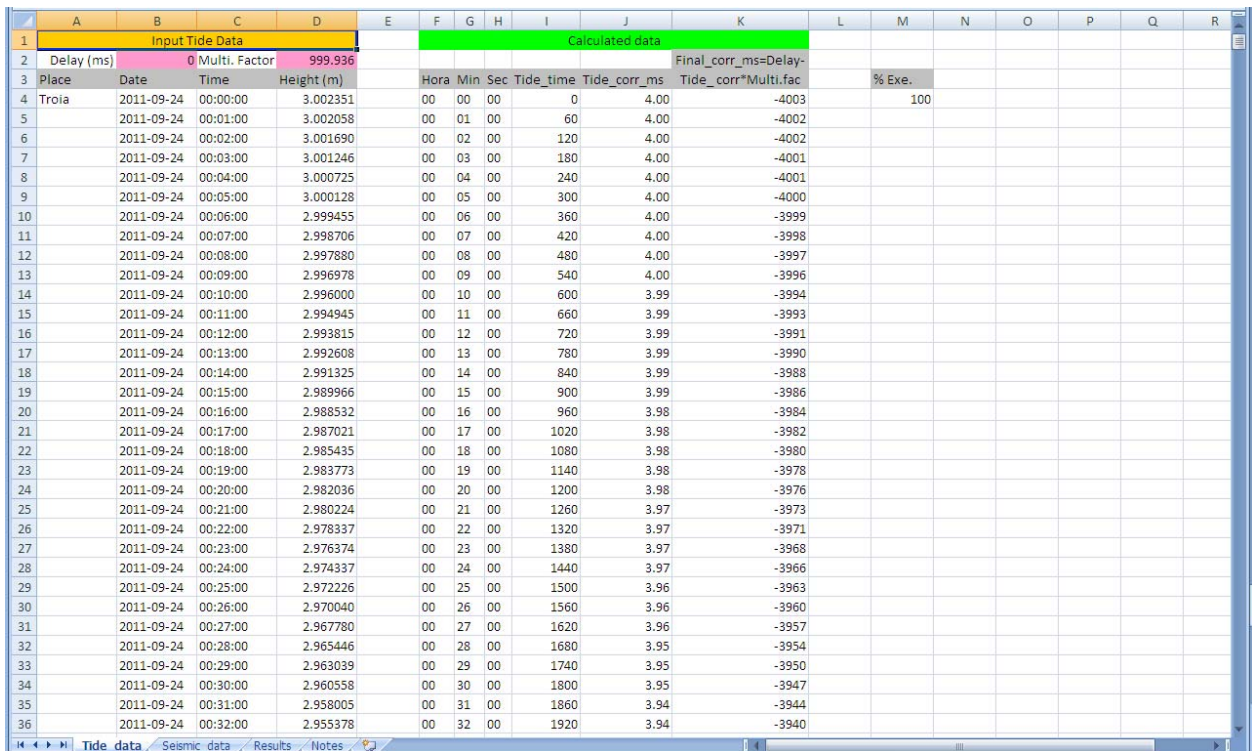
In the procedure adopted the value assigned to the delay was 0 (zero), since that the static shift for the tide correction was accommodated in the corrected seismic lines as negative time added at the beginning of the seismic traces. However, the delay field can be used to convert the computed corrections to positive numbers, by setting for the delay a fix value that should be higher than the maximum tidal height. The use of a positive value for the tidal correction preserves the beginning of the seismic traces, by alternatively clipping the correction time from the traces ending. This procedure can be particularly relevant if the trace length (time) of the original SEG-Y files has to be maintained after the tidal correction.

The multiplication by 0.75 was used to convert the tidal height (meters), to a static shift in two-way time expressed in milliseconds, assuming a velocity for the sound propagation in the water of 1500m/s. The additional multiplication factor was used with 2 objectives:

- 1 - To multiply by 1000 the value of the static shift correction (expressed in ms) in order to a) convert it into an integer (SEG-Y delay trace header field where the correction is going to be saved only allows integer values) and b) compatibilized the static shift correction with the time scale imposed to the seismic data during the importation into the Landmark environment;

2 - The assumed sample interval of 0.01953ms resulted from the rounding (into the tenth of ms) of the real 0.01953125ms sample rate. This rounding, introduces a small bias into the vertical (time) scale, in order to correct the value of the tide static shift for that bias it should be multiplied by 0.01953/0.01953125.

Thus, the multiplication factor adopted was 999.936, which results from the operation $1000 \cdot (0.01953/0.01953125)$.



Input Tide Data				Calculated data						
Delay (ms)	0	Multi. Factor	999.936	Final_corr_ms=Delay-						
Place	Date	Time	Height (m)	Hora	Min	Sec	Tide_time	Tide_corr_ms	Tide_corr*Multi.fac	% Exe.
Troia	2011-09-24	00:00:00	3.002351	00	00	00	0	4.00	-4003	100
	2011-09-24	00:01:00	3.002058	00	01	00	60	4.00	-4002	
	2011-09-24	00:02:00	3.001690	00	02	00	120	4.00	-4002	
	2011-09-24	00:03:00	3.001246	00	03	00	180	4.00	-4001	
	2011-09-24	00:04:00	3.000725	00	04	00	240	4.00	-4001	
	2011-09-24	00:05:00	3.000128	00	05	00	300	4.00	-4000	
	2011-09-24	00:06:00	2.999455	00	06	00	360	4.00	-3999	
	2011-09-24	00:07:00	2.998706	00	07	00	420	4.00	-3998	
	2011-09-24	00:08:00	2.997880	00	08	00	480	4.00	-3997	
	2011-09-24	00:09:00	2.996978	00	09	00	540	4.00	-3996	
	2011-09-24	00:10:00	2.996000	00	10	00	600	3.99	-3994	
	2011-09-24	00:11:00	2.994945	00	11	00	660	3.99	-3993	
	2011-09-24	00:12:00	2.993815	00	12	00	720	3.99	-3991	
	2011-09-24	00:13:00	2.992608	00	13	00	780	3.99	-3990	
	2011-09-24	00:14:00	2.991325	00	14	00	840	3.99	-3988	
	2011-09-24	00:15:00	2.989966	00	15	00	900	3.99	-3986	
	2011-09-24	00:16:00	2.988532	00	16	00	960	3.98	-3984	
	2011-09-24	00:17:00	2.987021	00	17	00	1020	3.98	-3982	
	2011-09-24	00:18:00	2.985435	00	18	00	1080	3.98	-3980	
	2011-09-24	00:19:00	2.983773	00	19	00	1140	3.98	-3978	
	2011-09-24	00:20:00	2.982036	00	20	00	1200	3.98	-3976	
	2011-09-24	00:21:00	2.980224	00	21	00	1260	3.97	-3973	
	2011-09-24	00:22:00	2.978337	00	22	00	1320	3.97	-3971	
	2011-09-24	00:23:00	2.976374	00	23	00	1380	3.97	-3968	
	2011-09-24	00:24:00	2.974337	00	24	00	1440	3.97	-3966	
	2011-09-24	00:25:00	2.972226	00	25	00	1500	3.96	-3963	
	2011-09-24	00:26:00	2.970040	00	26	00	1560	3.96	-3960	
	2011-09-24	00:27:00	2.967780	00	27	00	1620	3.96	-3957	
	2011-09-24	00:28:00	2.965446	00	28	00	1680	3.95	-3954	
	2011-09-24	00:29:00	2.963039	00	29	00	1740	3.95	-3950	
	2011-09-24	00:30:00	2.960558	00	30	00	1800	3.95	-3947	
	2011-09-24	00:31:00	2.958005	00	31	00	1860	3.94	-3944	
	2011-09-24	00:32:00	2.955378	00	32	00	1920	3.94	-3940	

Figure 5 – Tidal data worksheet of the Excel macro Mare_macro_v3.xls.

3.1.2 Seismic trace input worksheet

The seismic trace data must be imported into the seismic data worksheet (Figure 6). The spreadsheet is prepared to contemplate the 14 fields that were imported from the SEG-Y trace header files (point 2, page 7). However, only the 4 fields: Trace (number), Hour, Minute and Second are required for the computations.

The only computation made within this worksheet is the calculation of the field trace time, which corresponds to the trace time expressed in seconds.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Input Seismic Data															Calculated data			
2																Trace_time	% Exe.		
3	Linha	Trace	FFID	X	Y	GRP X	GRP Y	YEAR	DAY	HOUR	MINUTE	SECOND	TMBS	TWF					
4	scarps-55	1	4272	511952	4253247	-8863062	38427408	2011	267	8	41	47	406	0		31307		100	
5	scarps-55	2	4273	511952	4253248	-8863060	38427415	2011	267	8	41	47	781	0		31307			
6	scarps-55	3	4274	511952	4253249	-8863059	38427422	2011	267	8	41	48	171	0		31308			
7	scarps-55	4	4275	511952	4253249	-8863059	38427429	2011	267	8	41	48	578	0		31308			
8	scarps-55	5	4276	511952	4253250	-8863060	38427436	2011	267	8	41	48	875	0		31308			
9	scarps-55	6	4277	511952	4253251	-8863061	38427442	2011	267	8	41	49	281	0		31309			
10	scarps-55	7	4278	511952	4253252	-8863062	38427449	2011	267	8	41	49	656	0		31309			
11	scarps-55	8	4279	511952	4253252	-8863063	38427452	2011	267	8	41	50	46	0		31310			
12	scarps-55	9	4280	511952	4253253	-8863066	38427459	2011	267	8	41	50	453	0		31310			
13	scarps-55	10	4281	511951	4253253	-8863070	38427466	2011	267	8	41	50	750	0		31310			
14	scarps-55	11	4282	511951	4253254	-8863073	38427473	2011	267	8	41	51	156	0		31311			
15	scarps-55	12	4283	511951	4253255	-8863078	38427479	2011	267	8	41	51	546	0		31311			
16	scarps-55	13	4284	511950	4253256	-8863084	38427486	2011	267	8	41	51	921	0		31311			
17	scarps-55	14	4285	511950	4253256	-8863091	38427491	2011	267	8	41	52	328	0		31312			
18	scarps-55	15	4286	511949	4253257	-8863094	38427494	2011	267	8	41	52	625	0		31312			
19	scarps-55	16	4287	511949	4253257	-8863102	38427499	2011	267	8	41	53	31	0		31313			
20	scarps-55	17	4288	511948	4253258	-8863109	38427505	2011	267	8	41	53	406	0		31313			
21	scarps-55	18	4289	511947	4253258	-8863117	38427510	2011	267	8	41	53	796	0		31313			
22	scarps-55	19	4290	511947	4253259	-8863125	38427515	2011	267	8	41	54	203	0		31314			
23	scarps-55	20	4291	511946	4253259	-8863133	38427520	2011	267	8	41	54	500	0		31314			
24	scarps-55	21	4292	511945	4253260	-8863142	38427524	2011	267	8	41	54	906	0		31314			
25	scarps-55	22	4293	511944	4253260	-8863151	38427528	2011	267	8	41	55	281	0		31315			
26	scarps-55	23	4294	511944	4253261	-8863159	38427533	2011	267	8	41	55	671	0		31315			
27	scarps-55	24	4295	511943	4253261	-8863167	38427538	2011	267	8	41	56	78	0		31316			
28	scarps-55	25	4296	511943	4253262	-8863171	38427539	2011	267	8	41	56	375	0		31316			
29	scarps-55	26	4297	511942	4253262	-8863181	38427543	2011	267	8	41	56	781	0		31316			
30	scarps-55	27	4298	511941	4253262	-8863190	38427547	2011	267	8	41	57	156	0		31317			
31	scarps-55	28	4299	511940	4253263	-8863199	38427551	2011	267	8	41	57	546	0		31317			
32	scarps-55	29	4300	511939	4253263	-8863208	38427555	2011	267	8	41	57	953	0		31317			
33	scarps-55	30	4301	511939	4253264	-8863217	38427559	2011	267	8	41	58	250	0		31318			
34	scarps-55	31	4302	511938	4253264	-8863222	38427561	2011	267	8	41	58	656	0		31318			
35	scarps-55	32	4303	511937	4253264	-8863231	38427564	2011	267	8	41	59	31	0		31319			
36	scarps-55	33	4304	511937	4253265	-8863240	38427569	2011	267	8	41	59	421	0		31319			

Figure 6 – Seismic trace worksheet of the Excel macro Mare_macro_v3.xls.

3.1.3 Results worksheet

In the results worksheet (Figure 7), under the title “tide corrections”, are recorded the trace number and the correspondent computed final static shift (in ms) required for correct the vertical shift induced by the tide. Besides the tide correction data, several other data are recorded in the results worksheet for quality control purposes. Two graphics are also displayed, where the seismic trace numbers are plotted against the tide correction (two way time in ms) and the time differences between the seismic traces and tide data time tags.

The resultant worksheet of each seismic line was exported into an ASCII tab delimited text file named “Tide_SCARPS_XX.txt” where XX corresponds to the seismic line number.

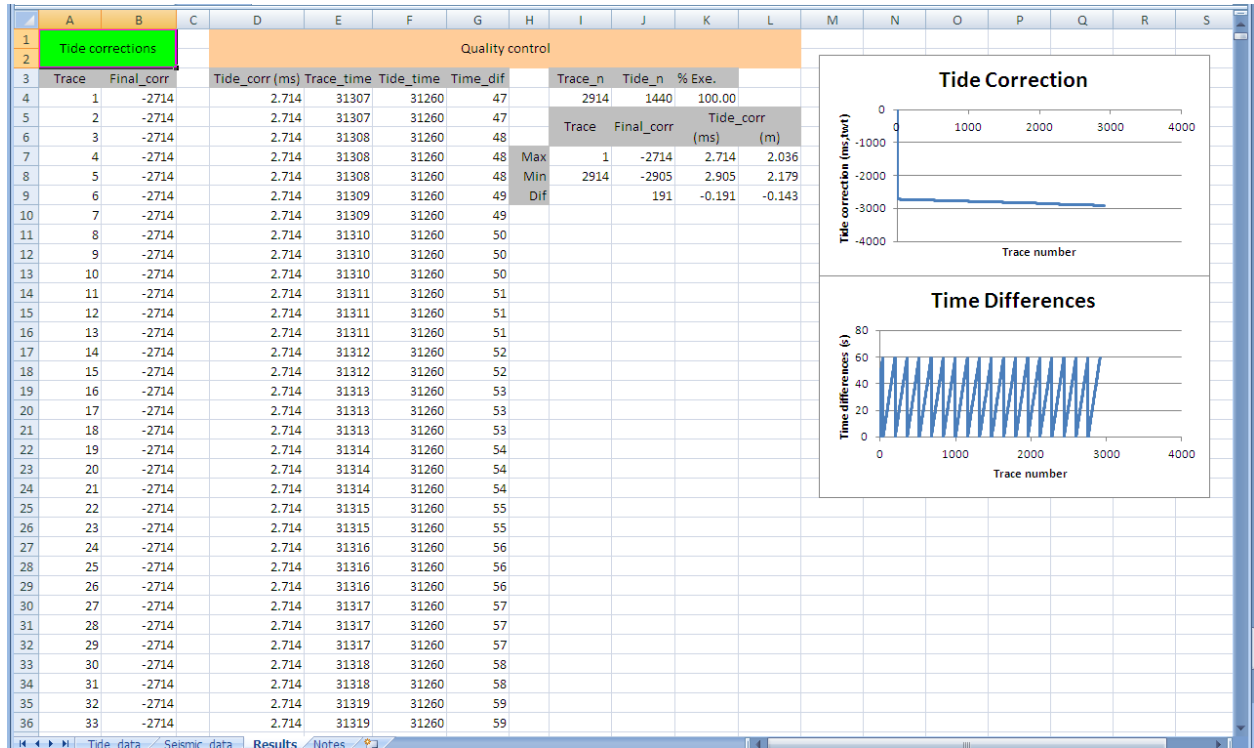


Figure 7 – Results worksheet of the Excel macro Mare_macro_v3.xls.

3.2 ASCII files reformat (Step 3, Figure 3)

It was prepared an ASCII text file with the header required by the SeisSee software for the importation of the two intended SEG-Y trace header fields. This ASCII file, which will be used as target file for the reformatted dataset to import, was then replicated for each seismic line and saved with the name “header_XX.txt” where XX corresponds to the seismic line number.

The GAWK (version 3.1.3), GNU implementation of awk programming language for windows, was used to reformat the ASCII files according with the requirements of the SeisSee.

It was prepared an ASCII text file, to run as batch, with a GAWK printf statement for each seismic line as depicted in the Figure 8¹. By running this batch file all the pre-prepared header_xx.txt files were populated with the data to import into the SEG-Y files (Figure 9).

¹ Note that to run this statement under the command line prompt the doubled % symbol must be replaced by a unique one.

```
gawk_v3.bat.txt*
gawk "NR>3 {printf(\"%11i %10i %10i\n\", $1, $1, $2)}" Tide_scarps_01.txt >> header_01.txt
gawk "NR>3 {printf(\"%11i %10i %10i\n\", $1, $1, $2)}" Tide_scarps_02.txt >> header_02.txt
gawk "NR>3 {printf(\"%11i %10i %10i\n\", $1, $1, $2)}" Tide_scarps_02T.txt >> header_02T.txt
gawk "NR>3 {printf(\"%11i %10i %10i\n\", $1, $1, $2)}" Tide_scarps_03.txt >> header_03.txt
.
.
gawk "NR>3 {printf(\"%11i %10i %10i\n\", $1, $1, $2)}" Tide_scarps_70.txt >> header_70.txt
gawk "NR>3 {printf(\"%11i %10i %10i\n\", $1, $1, $2)}" Tide_scarps_teste_01.txt >> header_teste_01.txt
gawk "NR>3 {printf(\"%11i %10i %10i\n\", $1, $1, $2)}" Tide_scarps_teste_02.txt >> header_teste_02.txt
```

Figure 8 – Extract of the ASCII text file prepared for running the gawk to reformat the data.

header_55.txt *		
P	F	Trace index in file
P	F	* Trace sequence number within line
P109	F 2	Delay Recording time
1	1	-2714
2	2	-2714
3	3	-2714
4	4	-2714
5	5	-2714
6	6	-2714
7	7	-2714
8	8	-2714
9	9	-2714
10	10	-2714
11	11	-2714
12	12	-2714
...

Figure 9 – Example of the beginning of the ASCII text file prepared, for the SCARPS seismic line number 55, for the importation of the “trace sequence number within line” and “delay recording time” data into the SEG-Y trace header files, using the SeisSee software.

3.3 Import into the SEG-Y header files of the trace static shift data (Step 4, Figure 3)

The SEG-Y trace header field chosen for saving the tide correction static shift data was the delay recording time (DELRECT, bytes 109-110). This field was selected since that it is usually read by the seismic data interpretation software’s.

The SEG-Y field trace sequence number within line (SEQWL, bytes 1-4) wasn’t populated in the original SEG-Y files. Since that this field is required to import the data into some seismic data interpretation software’s, it was decided to populate it.

To import the data into the SEG-Y DELRECT and SEQWL trace headers I have used the software SeisSee (version 2.16.2, build Feb 17 2012). Each raw SEG-Y file was opened with the SeisSee software and using the functionality “File/Import trace header from ASCII file” the data prepared to populate the header fields DELRECT and SEQWL were uploaded into the SEG-Y files. Note that the updated SEG-Y files have the same name as the original ones. However, copies of the original data were maintained in a different folder.

During the importation of the seismic data into the landmark environment, as the DELRECT field was read and the corresponded static correction applied, the tide induced vertical displacement was corrected (Figure 10).

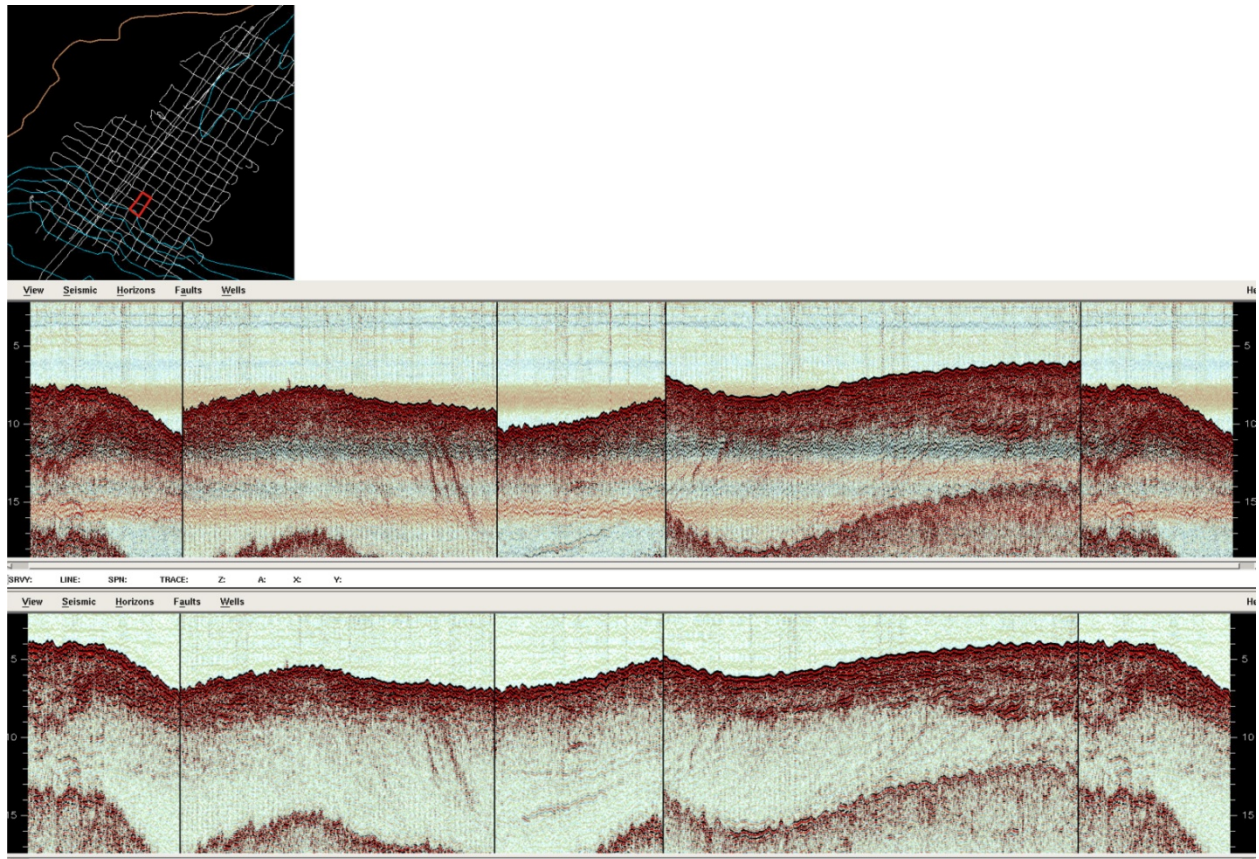


Figure 10 – Example of a Landmark loop display with segments of SCARPS seismic lines (20, 01, 18, 02, 20) without tide correction (upper panel) and with tide correction (lower panel). The location of the 4 seismic line segments that form the loop is indicated by the red rectangle on the upper left map.

4 Landmark environment

A new Landmark project was created for the processing and interpretation of the SCARPS seismic reflection data (Table 2).

Table 2 – Main parameters of the landmark project created for the processing and interpretation of the SCARPS seismic reflection data.

Parameter	Attribute
Project Name	SCARPS

Parameter	Attribute
District	DGMSID
Project directory path	/raid01/oracle/orahome1/oradata/DGMSID/owprojects
Seismic file storage	/lacedistrict/projman/seis-data/SCARPS_s
Coordinates	WGS84, UTM zone 29
Xmin	480 000
Xmax	530 000
Ymin	4 200 000
Ymax	4 300 000

From each SEG-Y seismic file imported, 10 versions of 32 bytes vertical seismic files were created in the landmark (Table 3). The naming of those file version follows a scheme where the first 3 characters denote the type of seismic processing; the next 2 characters indicate the file resolution (8, 16 or 32 bytes) and the remaining characters are allocated to the file version. In the 3 additional extension characters, the first 2 are allocated to the vertical scale status, standing “x3” for a 1000 multiplication factor, “x1” for a 10 multiplication factor and the “ed” for the edited (real) scale; finally the last character “t” denote the tide vertical correction.

Table 3 – Names and main characteristics of the vertical seismic files versions created in the Landmark environment

Vertical file version	Characteristics
Raw3200001.x3_	Raw data, vertical scale x1000, without tide correction
Raw3200001.x3t	Raw data, vertical scale x1000, with tide correction
Raw3200002.ed_	Raw data, edited vertical scale, without tide correction
Raw3200002.edt	Raw data, edited vertical scale, with tide correction
Fil3200001.edt	Filtered (filter 1) data, real edited vertical scale
Fil3200002.edt	Filtered (filter 2) data, real edited vertical scale
Dss3200001.edt	Dip-scan (window 3 traces) data, real edited vertical scale
Dss3200002.edt	Dip-scan (window 5 traces) data, real edited vertical scale
Trm3200001.edt	Trace mixed (window 3 traces) data, real edited vertical scale
Trm3200001.x1t	For reflection picking, trace mixed, x10 edited vertical scale

4.1 Import of SEG-Y files (Step 5, Figure 3)

The SEG-Y files with the edited trace headers were imported into the Landmark project using to different flows of the *PostStack* data loader module. In both flows the SEG-Y sample rate was overridden with the value 19.53ms (1000multiplication factor) and the trace maximum time was limited to 100 000ms. The data was then resampled for 20ms, using the *anti-alias* filter option of the *PostStack* resampling operator.

The vertical files Raw3200001.x3_ (*PostStack* session: raw_01) does not have tide correction since that the *read delay recording time* option was disable. This files version are the most closer to the

original raw files and can be useful during the interpretation for example to check the multiple reflection arrival time.

The vertical files Raw3200001.x3t (*PostStack* session: raw_02) already have the tide correction since that the *read delay recording time* option was active during the upload. The value correspondent to the maximum static shift (4374, posteriori rounded to 4.3ms) was added as negative time at the beginning of all seismic traces.

Both Raw3200001.x3_ and Raw3200001.x3t vertical files were duplicated into the files Raw3200002.ed_ and Raw3200002.edt (Figure 11), respectively. The sample rates of these new files were then manually edited to the value 0.02ms. In the files Raw3200002.edt the initial time was also edited accordingly to 4.3ms. After these procedures the seismic lines of the files Raw3200002.edt are corrected for the tidal shift and its vertical datum is also concordant with the hydrographic zero used as vertical datum for the local hydrographic charts (ordnance datum).

4.2 Filter, 2 options (Step 6, Figure 3)

Since that the landmark filter operators are limited to 10000Hz, the bandpass filters were applied to the file versions with the 1000x vertical exaggerated scale. Thus, the values of the frequency intervals used to configure the filters corresponded to the pretended values divided by 1000 and therefore do not exceed the allowed high frequency limit.

Two Ormsby bandpass filter configurations were used (Table 4).

Table 4 – Frequencies (in Hz) used in the parameterization of the bandpass filters. In brackets is indicated the real frequencies that correspond to the ones introduced in the *PostStack* filter operator multiplied by 1000.

	Filter 1	Filter2
Low cut	0.6 (600Hz)	0.6 (600Hz)
low pass	1.2 (1 200Hz)	1.2 (1200Hz)
High cut	15 (15 000Hz)	12 (12 000Hz)
High pass	12 (12 000Hz)	10 (10 000Hz)

The vertical files Fil3200001.edt (*PostStack* session: fil_01) (Figure 11) resulted from the application of the filter 1 and the vertical files Fil3200002.edt (*PostStack* session: fil_01) resulted from the application of the filter 2. The sample rates of both these files were posteriori manually edited to the value 0.02ms.

4.3 Dip-scan stack and trace mix (Step 7, Figure 3)

Two different spatial filter operators were used to enhance the data. The dip-scan stack and the triangular trace mixing.

The files Dss3200001.edt (*PostStack* session: dss_01,) (Figure 11) and Dss3200001.edt (*PostStack* session: dss_02) resulted from the application to the file Fil3200001.edt of the dip-scan stack operator, configured to a time interval of -0.1 to +0.1ms and using a window of 3 traces and 5 traces, respectively. The 3 traces window produces a slightly cleaner output but in the deeper zones it is not as good as the one using 5 traces. Thus the file Dss3200001.edt is preferred to interpret the areas near the sea bottom and de file Dss3200002.edt to interpret the deeper zones.

The files trm3200001.edt (*PostStack* session: trm_01) (Figure 11) resulted from the application to the file Fil3200002.edt of the trace mix operator configured to a window of 3 traces using a triangular mean (25, 50, 25).

Generally the file Trm3200001.edt is the preferred one for the interpretation. Though, the files Dss3200001.edt and Dss3200002.edt are usually better for the areas with high dip reflections.

During the tests of reflections picking in the Landmark environment (Seisworks 2D), it was observed that the picked reflectors were miss-positioned by the software when the selected display had a vertical scale that implied interpolation (i.e. higher than zero). To circumvent this problem it was created a new files version, specifically for reflections picking, with a 10 times exaggerated vertical scale. This new file was named trm3200001.x1t and was produced by manually editing the sample rate of a copy of the trm3200001.edt files.

4.4 Export processed data to SEG-Y files

Two processed vertical seismic files, dip-san stack and trace mixed, both tide corrected, were exported into SEG-Y files using the *PostStack* data loader. This procedure was carried out in order to have a backup of the processed files that was independent of the Landmark software. With these processed files stored into standard SEG-Y (Rev1) files, the dataset can be accessed by any general seismic interpretation or visualization software.

The produced SEG-Y files were created using the default parameters of the Landmark *PostStack* data loader. There are 3 aspects of the produced SEG-Y files that should be noted:

1. Negative (-4ms) Delay Recording Time (bytes 109-110) field. The negative 4.3ms time added by the tide correction is rounded into 4ms and stored as a negative Delay Recording Time. The fields Mute Time Start (bytes 111-112) and Mute Time End (bytes 113-114) are also populated with the value -4;

2. The projected (WGS84, UTM zone 29) coordinates are stored in the fields CDPx (181-184), CDPy (185-188). These coordinates are affected by a scale factor of -100, that is stored in the Scaler to All Coordinates field (bytes 71-72);
3. Binary header with wrong (19 μ m instead of 20 μ m) sample rate. Despite the resample procedures the new sample rate only was actualized in the trace header and the binary header remained with the original stored wrong sample rate. To overcome this problem the SeisSee (version 2.16.2, build Feb 17 2012) software was used to edit the binary header of the exported SEG-Y files, replacing the sample rate values from 19 μ m to 20 μ m.

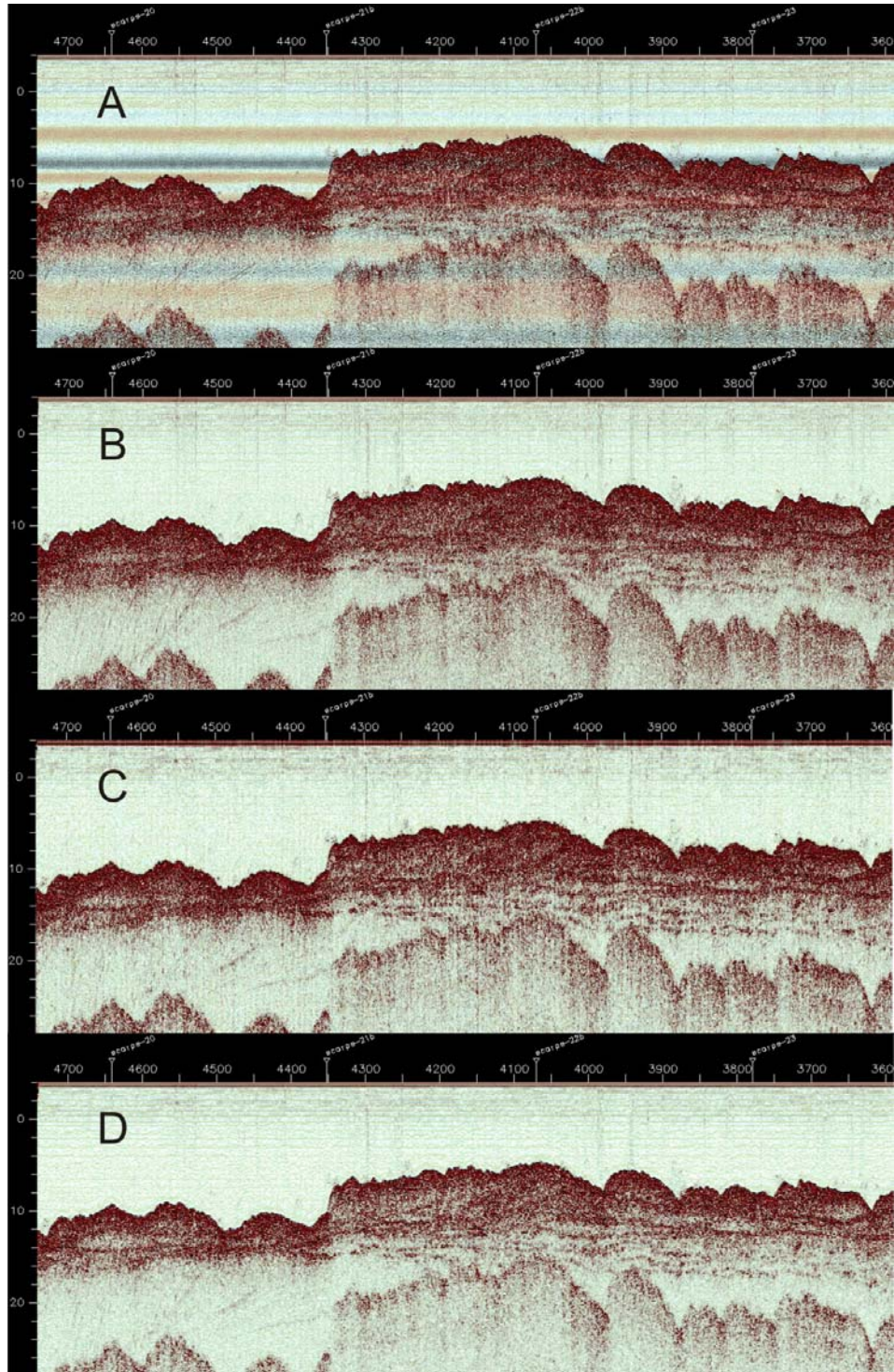


Figure 11 – Excerpt of the seismic line SCARPS_05 (channel 1) resampled (A), with the band pass filter 1 (B), with dip-scan stack 1 (C) and with triangular trace mixing (D). Vertical axis in ms (100ms \approx 75m) and horizontal axis in seismic traces (100 traces \approx 80m)

5 Annexes

5.1. Seismic data location maps

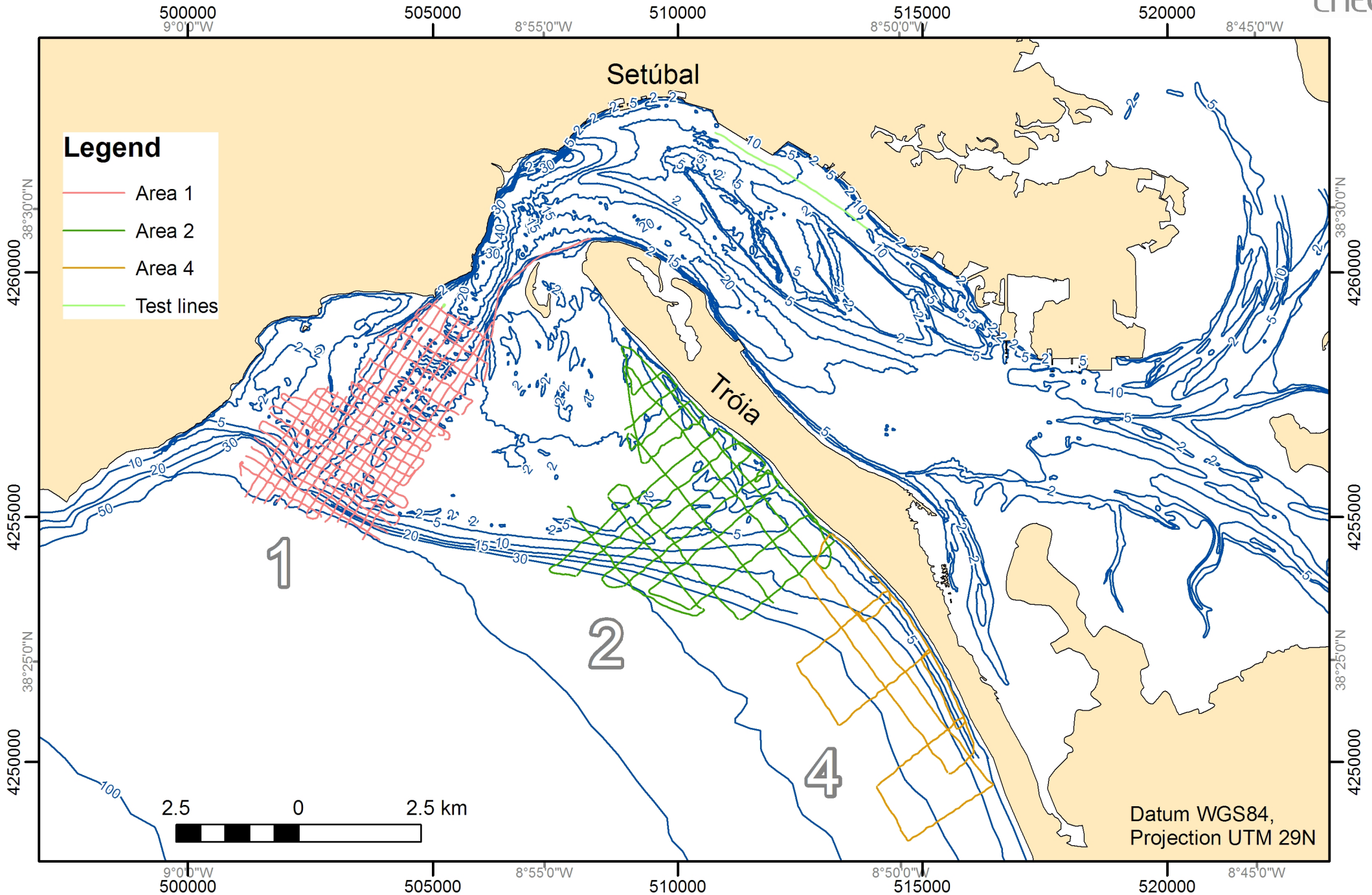
5.2. Seismic data metadata

5.3. Visual basic Excel macro mare_macro_v3 code

5.1 Data location maps

Cruise SCARPS: General Map of the Survey Area

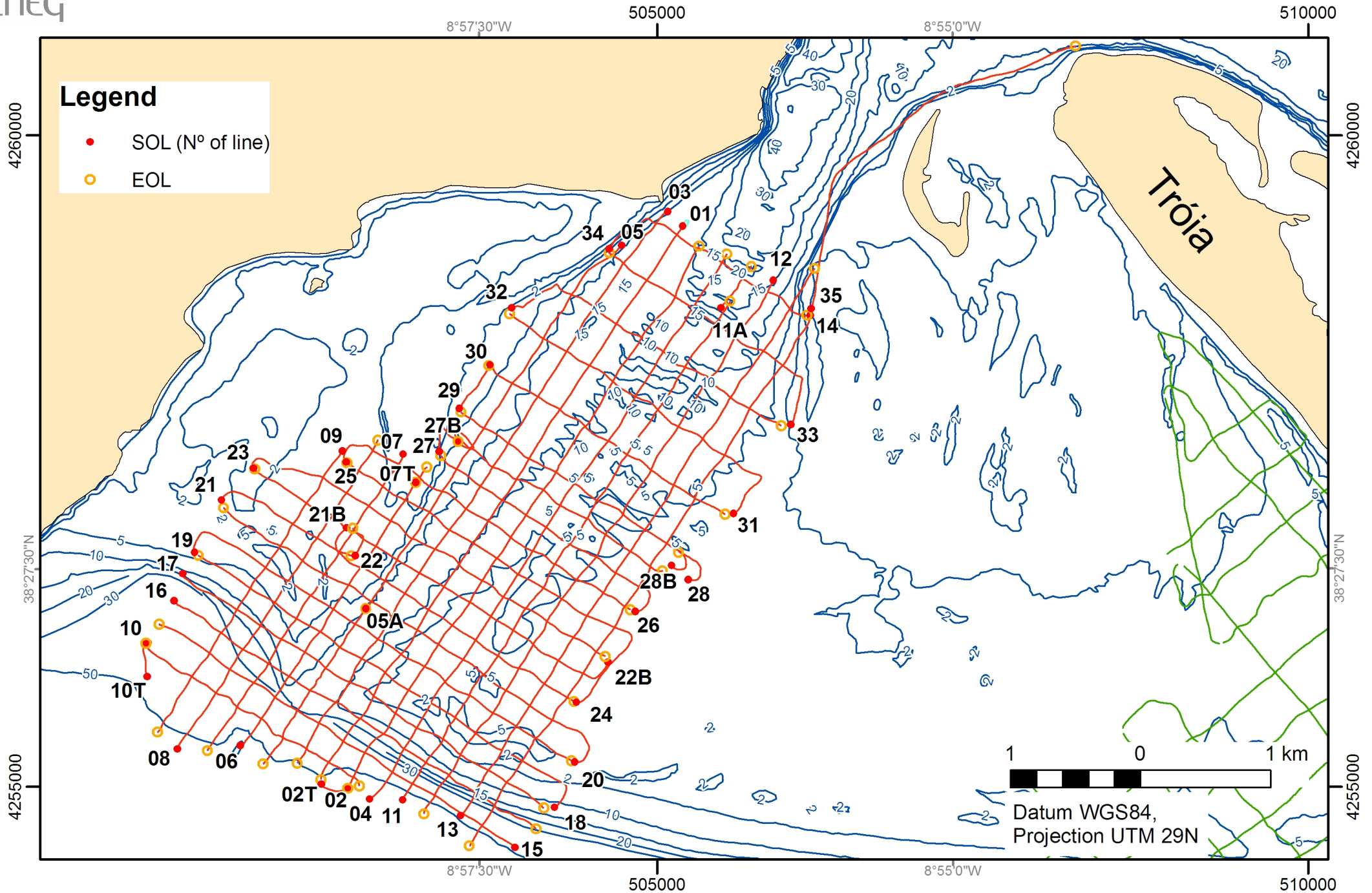
19-25 Set. 2011





Cruise SCARPS: Map of the Survey Area 1

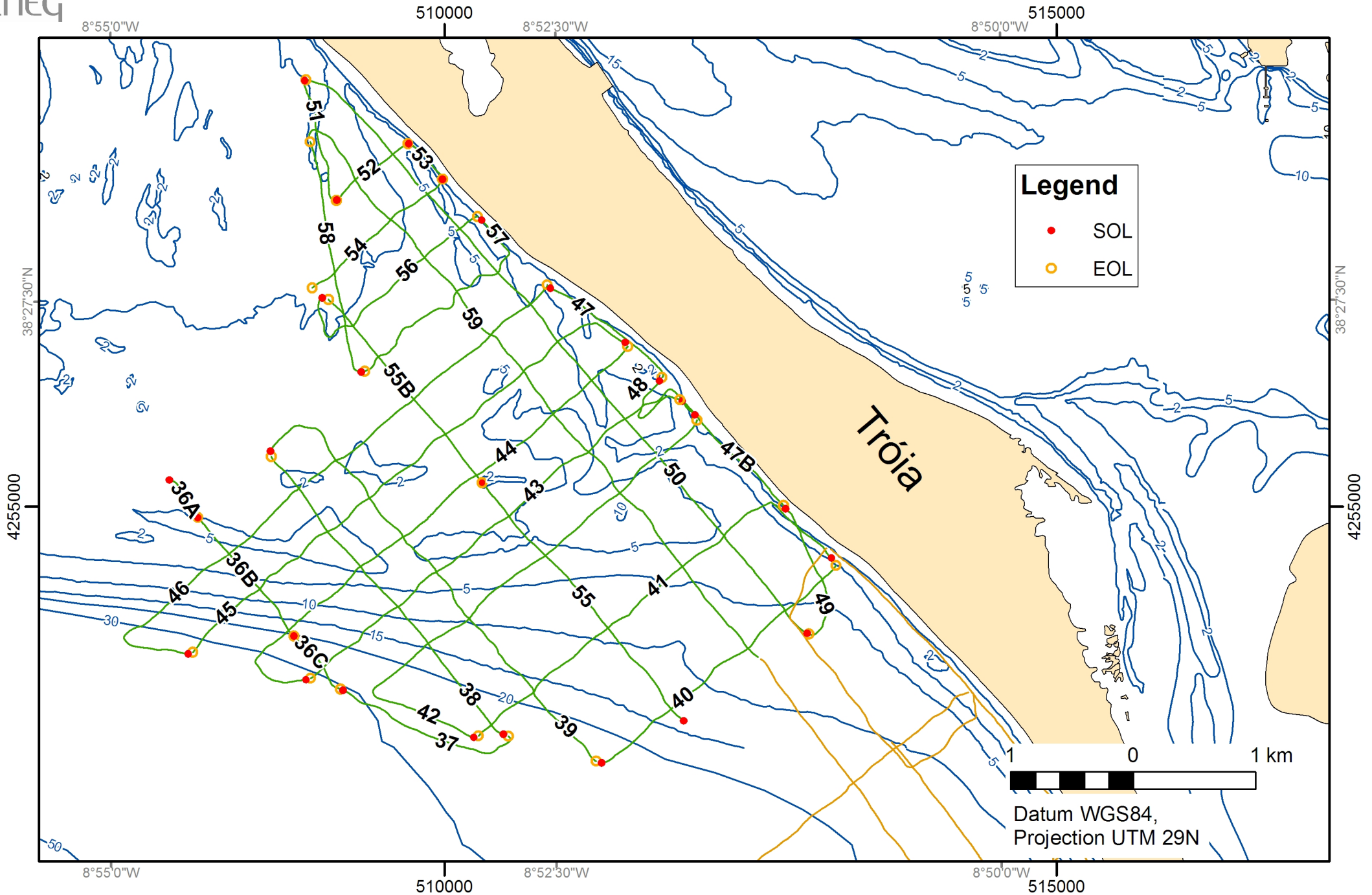
19-25 Set. 2011





Cruise SCARPS: Map of the Survey Area 2

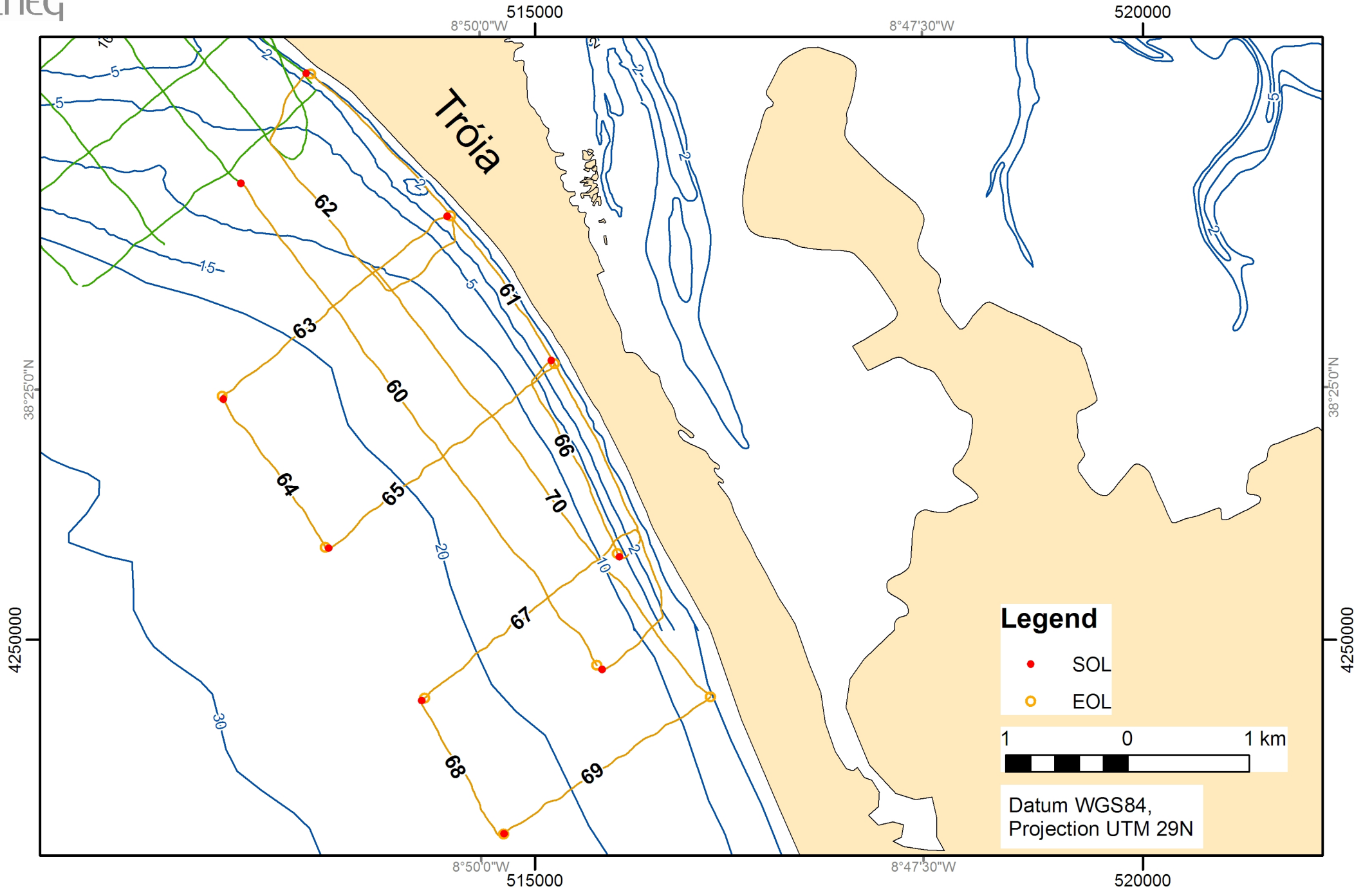
19-25 Set. 2011





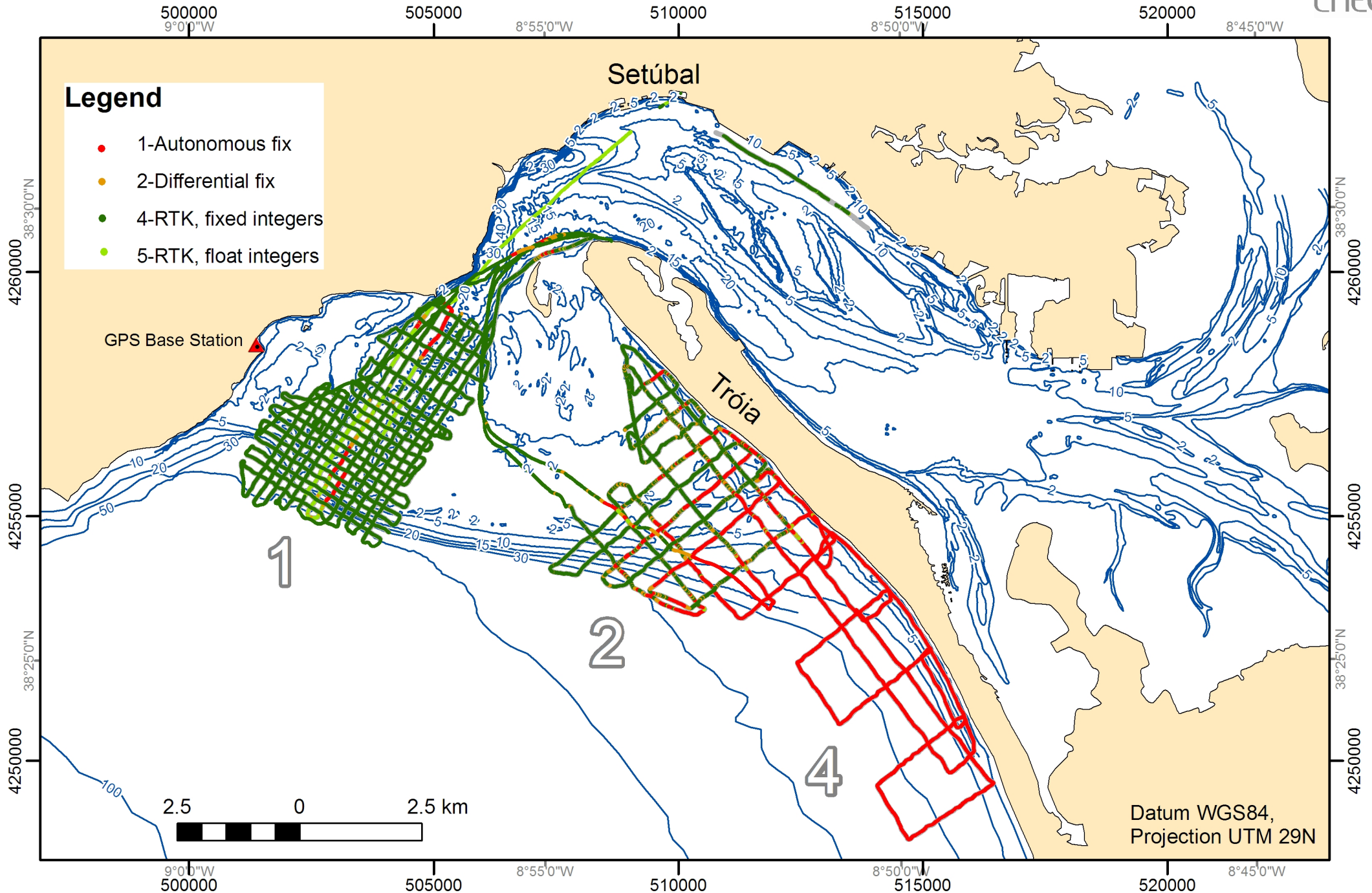
Cruise SCARPS: Map of the Survey Area 4

19-25 Set. 2011



Cruise SCARPS: GPS Quality Position Map

19-25 Set. 2011



5.2 Seismic data metadata

List of seismic data files types and respective backup DVD's

NAME	FILE	Raw file existence (Yes/No)*	DATE (ddmmyyyy)	SOL (hours)	SOL (min)	SOL (sec)	EOL (hours)	EOL (min)	EOL (sec)	SURVEY AREA	TRACE NUMBER	SAMPLE INTERVAL (ms)**	NUMBER of SAMPLES	LINE LENGTH (m)	OBSERVATIONS
SCARPS-01	Hunteclnt_2011_263_12_36_41	No	20092011	12	36	41	13	17	34	1	6543	0.019	5120	5951.0	
SCARPS-02	Hunteclnt_2011_263_13_19_59	No	20092011	13	20	0	14	5	46	1	7326	0.019	5120	5972.0	
SCARPS-02T	Hunteclnt_2011_263_14_09_59	No	20092011	13	17	55	13	19	58	1	330	0.019	5120	253.3	
SCARPS-03	Hunteclnt_2011_263_14_17_52	No	20092011	14	17	52	15	4	1	1	7384	0.019	5120	6165.0	
scarps-04	Hunteclnt_2011_263_15_09_28	No	20092011	15	9	28	15	44	31	1	5608	0.019	5120	5698.0	
scarps-05	Hunteclnt_2011_264_07_30_22	No	21092011	7	30	22	7	59	59	1	4741	0.019	5120	4071.0	
scarps-05A	Hunteclnt_2011_264_08_00_00	No	21092011	8	0	0	8	12	46	1	2044	0.019	5120	1724.2	
scarps-06	Hunteclnt_2011_264_08_42_09	No	21092011	8	42	9	9	0	0	1	2856	0.019	5120	2815.0	
scarps-07	Hunteclnt_2011_264_09_03_18	No	21092011	9	3	18	9	24	37	1	3410	0.019	5120	3184.0	
scarps-07T	Hunteclnt_2011_264_09_00_00	No	21092011	9	0	0	9	1	7	1	179	0.019	5120	169.8	
scarps-08	Hunteclnt_2011_264_09_26_57	No	21092011	9	26	58	9	49	33	1	3616	0.019	5120	3309.0	
scarps-09	Hunteclnt_2011_264_09_52_11	No	21092011	9	52	11	10	11	31	1	3093	0.019	5120	3002.0	
scarps-10	Hunteclnt_2011_264_10_18_22	No	21092011	10	18	22	10	33	59	1	2500	0.019	5120	2314.0	
scarps-10T	Hunteclnt_2011_264_10_15_16	No	21092011	10	15	16	10	18	20	1	491	0.019	5120	423.4	
scarps-11A	Hunteclnt_2011_264_11_21_27	No	21092011	11	21	28	11	25	21	1	625	0.019	5120	481.9	
scarps-11	Hunteclnt_2011_264_10_37_55	No	21092011	10	37	55	11	18	37	1	6513	0.019	5120	5483.0	Stop line to fill up big generator
scarps-12	Hunteclnt_2011_264_11_27_13	No	21092011	11	27	14	11	59	44	1	5202	0.019	5120	5531.0	
scarps-13	Hunteclnt_2011_264_12_05_58	No	21092011	12	5	58	12	48	0	1	6728	0.019	5120	5909.0	
scarps-14	Hunteclnt_2011_264_12_56_00	No	21092011	12	56	0	13	28	45	1	5241	0.019	5120	5484.0	
scarps-15	Hunteclnt_2011_264_13_33_02	Yes	21092011	13	33	3	13	56	17	1	3719	0.019	5120	3697.0	
scarps-16	Hunteclnt_2011_264_13_58_20	Yes	21092011	13	58	20	14	24	27	1	4178	0.019	5120	3838.0	
scarps-17	Hunteclnt_2011_265_07_24_27	Yes	22092011	7	24	27	7	49	4	1	3940	0.019	5120	3824.0	
scarps-18	Hunteclnt_2011_265_07_49_41	Yes	22092011	7	49	41	8	16	21	1	4268	0.019	5120	4078.0	
scarps-19	Hunteclnt_2011_265_08_16_37	Yes	22092011	8	16	37	8	42	11	1	4091	0.019	5120	4029.0	
scarps-20	Hunteclnt_2011_265_08_42_24	Yes	22092011	8	42	24	9	9	34	1	4347	0.019	5120	4103.0	
scarps-21B	Hunteclnt_2011_265_10_08_12	Yes	22092011	10	8	13	10	24	46	1	2648	0.019	5120	2701.0	
scarps-21	Hunteclnt_2011_265_09_10_01	Yes	22092011	9	10	2	9	18	26	1	1346	0.019	5120	1309.0	Line terminated – shipping in channel
scarps-22B	Hunteclnt_2011_265_09_50_19	Yes	22092011	9	50	19	10	7	49	1	2800	0.019	5120	2706.0	
scarps-22	Hunteclnt_2011_265_09_18_42	Yes	22092011	9	18	42	9	27	20	1	1380	0.019	5120	1319.0	Line terminated – shipping in channel
scarps-23	Hunteclnt_2011_265_09_27_24	Yes	22092011	9	27	25	9	49	55	1	3602	0.019	5120	3612.0	Passed close to stern of cargo carrier
scarps-24	Hunteclnt_2011_265_10_24_54	Yes	22092011	10	24	55	10	48	31	1	3779	0.019	5120	3727.0	
scarps-25	Hunteclnt_2011_265_10_48_35	Yes	22092011	10	48	36	11	6	57	1	2939	0.019	5120	3009.0	
scarps-26	Hunteclnt_2011_265_11_07_14	Yes	22092011	11	7	15	11	25	45	1	2963	0.019	5120	2513.0	Reduce speed to improve noise conditions
scarps-27B	Hunteclnt_2011_265_11_33_20	Yes	22092011	11	33	20	11	48	1	1	2351	0.019	5120	2159.0	
scarps-27	Hunteclnt_2011_265_11_26_05	Yes	22092011	11	26	5	11	33	19	1	1158	0.019	5120	887.9	Circle to avoid traffic
scarps-28B	Hunteclnt_2011_265_12_00_51	Yes	22092011	12	0	51	12	18	8	1	2764	0.019	5120	2609.0	
scarps-28	Hunteclnt_2011_265_11_49_33	Yes	22092011	11	49	33	11	53	3	1	561	0.019	5120	442.8	Line terminated - Snagged buoy
scarps-29	Hunteclnt_2011_265_12_18_23	Yes	22092011	12	18	23	12	22	11	1	607	0.019	5120	481.7	
scarps-30	Hunteclnt_2011_265_12_22_16	Yes	22092011	12	22	17	12	38	57	1	2668	0.019	5120	2501.0	
scarps-31	Hunteclnt_2011_265_12_39_31	Yes	22092011	12	39	32	13	2	24	1	3660	0.019	5120	3164.0	
scarps-32	Hunteclnt_2011_265_13_03_00	Yes	22092011	13	3	1	13	26	15	1	3720	0.019	5120	2924.0	
scarps-33	Hunteclnt_2011_265_13_27_02	Yes	22092011	13	27	2	13	45	49	1	3006	0.019	5120	2504.0	
scarps-34	Hunteclnt_2011_265_13_46_07	Yes	22092011	13	46	8	14	2	24	1	2604	0.019	5120	2165.0	
scarps-35	Hunteclnt_2011_265_14_03_01	Yes	22092011	14	3	1	14	32	59	1	4796	0.019	5120	3657.0	Transit line to Marina
scarps-36A	Hunteclnt_2011_266_07_26_05	Yes	23092011	7	26	5	7	29	15	2	509	0.019	5120	462.5	
scarps-36B	Hunteclnt_2011_266_07_29_15	Yes	23092011	7	29	16	7	38	49	2	1531	0.019	2560	1452.0	changed sampling window
scarps-36C	Hunteclnt_2011_266_07_38_50	Yes	23092011	7	38	50	7	43	12	2	701	0.019	3840	697.6	changed sampling window
scarps-37	Hunteclnt_2011_266_07_43_23	Yes	23092011	7	43	23	7	54	52	2	1838	0.019	4096	1762.0	changed sampling window
scarps-38	Hunteclnt_2011_266_07_55_10	Yes	23092011	7	55	10	8	16	17	2	3378	0.019	4096	3411.0	
scarps-39	Hunteclnt_2011_266_08_16_35	Yes	23092011	8	16	35	8	47	8	2	4889	0.019	4096	4715.0	
scarps-40	Hunteclnt_2011_266_08_47_30	Yes	23092011	8	47	30	9	5	50	2	2933	0.019	4096	2902.0	
scarps-41	Hunteclnt_2011_266_09_06_23	Yes	23092011	9	6	23	9	35	10	2	4608	0.019	4096	4405.0	
scarps-42	Hunteclnt_2011_266_09_35_30	Yes	23092011	9	35	30	10	7	20	2	5095	0.019	4096	5056.0	
scarps-43	Hunteclnt_2011_266_10_07_41	Yes	23092011	10	7	41	10	41	1	2	5334	0.019	4096	4828.0	
scarps-44	Hunteclnt_2011_266_10_41_20	Yes	23092011	10	41	20	11	15	0	2	5388	0.019	4096	5262.0	
scarps-45	Hunteclnt_2011_266_11_15_20	Yes	23092011	11	15	20	11	52	5	2	5880	0.019	4096	5387.0	

NAME	FILE	Raw file existence (Yes/No)*	DATE (ddmmyyyy)	SOL (hours)	SOL (min)	SOL (sec)	EOL (hours)	EOL (min)	EOL (sec)	SURVEY AREA	TRACE NUMBER	SAMPLE INTERVAL (ms)**	NUMBER of SAMPLES	LINE LENGTH (m)	OBSERVATIONS
scarps-46	Hunteclnt_2011_266_11_52_25	Yes	23092011	11	52	25	12	30	26	2	6083	0.019	4096	5917.0	
scarps-47B	Hunteclnt_2011_266_12_46_30	Yes	23092011	12	46	30	12	55	25	2	1427	0.019	4096	1393.0	
scarps-47	Hunteclnt_2011_266_12_31_18	Yes	23092011	12	31	18	12	40	9	2	1415	0.019	4096	1413.0	
scarps-48	Hunteclnt_2011_266_12_40_25	Yes	23092011	12	40	25	12	46	20	2	947	0.019	4096	874.7	Transit Line to avoid beach corridor
scarps-49	Hunteclnt_2011_266_12_55_40	Yes	23092011	12	55	40	13	4	44	2	1453	0.019	4096	1338.0	
scarps-50	Hunteclnt_2011_266_13_04_51	Yes	23092011	13	4	51	13	54	14	2	7904	0.019	4096	7254.0	
scarps-51	Hunteclnt_2011_266_13_54_20	Yes	23092011	13	54	20	14	1	42	2	1179	0.019	4096	1153.0	
scarps-52	Hunteclnt_2011_266_14_01_43	Yes	23092011	14	1	44	14	7	5	2	858	0.019	4096	868.0	
scarps-53	Hunteclnt_2011_266_14_07_08	Yes	23092011	14	7	8	14	10	1	2	463	0.019	4096	475.3	Alter Course
scarps-54	Hunteclnt_2011_266_14_10_02	Yes	23092011	14	10	2	14	20	49	2	1725	0.019	4096	1632.0	
scarps-55B	Hunteclnt_2011_267_09_00_00	Yes	24092011	9	0	0	9	13	6	2	2099	0.019	4096	2215.0	
scarps-55	Hunteclnt_2011_267_08_41_47	Yes	24092011	8	41	47	8	59	59	2	2914	0.019	4096	2961.0	
scarps-56	Hunteclnt_2011_267_09_13_30	Yes	24092011	9	13	30	9	27	54	2	2304	0.019	4096	2236.0	
scarps-57	Hunteclnt_2011_267_09_28_15	Yes	24092011	9	28	15	9	43	40	2	2467	0.019	4096	2291.0	
scarps-58	Hunteclnt_2011_267_09_43_55	Yes	24092011	9	43	55	9	56	41	2	2044	0.019	4096	2092.0	
scarps-59	Hunteclnt_2011_267_09_56_57	Yes	24092011	9	56	57	10	42	22	2	7268	0.019	4096	6791.0	
scarps-60	Hunteclnt_2011_267_10_42_35	Yes	24092011	10	42	35	11	20	0	4	5987	0.019	4096	5728.0	
scarps-61	Hunteclnt_2011_267_11_20_25	Yes	24092011	11	20	25	12	4	49	4	7103	0.019	4096	6964.0	
scarps-62	Hunteclnt_2011_267_12_05_07	Yes	24092011	12	5	7	12	28	32	4	3748	0.019	4096	3577.0	
scarps-63	Hunteclnt_2011_267_12_28_45	Yes	24092011	12	28	46	12	47	37	4	3019	0.019	4096	2794.0	
scarps-64	Hunteclnt_2011_267_12_47_51	Yes	24092011	12	47	51	12	59	7	4	1804	0.019	4096	1708.0	
scarps-65	Hunteclnt_2011_267_12_59_21	Yes	24092011	12	59	21	13	16	36	4	2761	0.019	4096	2773.0	
scarps-66	Hunteclnt_2011_267_13_17_02	Yes	24092011	13	17	2	13	31	0	4	2234	0.019	4096	2093.0	
scarps-67	Hunteclnt_2011_267_13_31_15	Yes	24092011	13	31	15	13	55	42	4	3911	0.019	4096	3092.0	Speed reduction in line to improve noise level
scarps-68	Hunteclnt_2011_267_13_56_00	Yes	24092011	13	56	0	14	7	35	4	1853	0.019	4096	1541.0	
scarps-69	Hunteclnt_2011_267_14_07_38	Yes	24092011	14	7	38	14	23	54	4	2603	0.019	4096	2380.0	
scarps-70	Hunteclnt_2011_267_14_24_00	Yes	24092011	14	24	0	15	0	40	4	5867	0.019	4096	5352.0	
teste-01	Hunteclnt_2011_263_10_29_57	No	20092011	10	29	58	10	59	4	0	4658	0.019	4096	4270.0	
teste-02	Hunteclnt_2011_263_12_34_29	No	20092011	12	34	29	12	36	40	0	350	0.019	4096	173.0	

* Raw data save in channel 2 with filename HuntecExt...

** Sample interval recorded in the SEG Y files (19us), however the real sample interval is 0.01953125ms or 19,53125us, that resulted from a sampling rate of 51.2kHz.

5.3 Code of Excel macro Mare_macro_v3.xls

Public nLinhas As Integer
Public nTracos As Integer
Public nTide As Integer

Public Sub vernumero() ' vê qual o nº de dados contando as linhas da 1ª coluna

nLinhas = 0

'Inicia um ciclo:

For a = 5 To 65536 'da 5ª linha até a um limite de 65536 registos

If Cells(a, 2).Value = "" Then 'Verifica qual a 1ª linha sem registos na 2ª coluna...

nLinhas = a - 1 'Quando encontra, passa o valor(nº da linha) para a variável Indíce

Exit For 'sai do ciclo.

End If

Next a

End Sub

Sub Corr_Mare()

' determina o nº de linhas com dados de sismica (nº de traços)

nTracos = 0

Sheets("Seismic_data").Select

vernumero

nTracos = nLinhas

Sheets("results").Cells(4, 9).Value = nTracos - 3 'escreve nº de traços

'preenche a coluna do Trace_time

For n = 4 To nTracos

Sheets("Seismic_data").Cells(n, 16).FormulaR1C1 = "=(RC[-6]*3600)+(RC[-5]*60)+RC[-4]"

Cells(4, 18).Value = (n / nTracos) * 100 'escreve a % de execução

Next n

para = 1

' determina o nº de linhas com dados de maré

nTide = 0

Sheets("Tide_data").Select

vernumero

nTide = nLinhas

Sheets("results").Cells(4, 10).Value = nTide - 3 'escreve nº de registos de maré

'preenche as colunas do "Calculated data" de maré

Sheets("Tide_data").Select

For n = 4 To nTide

Cells(n, 6).FormulaR1C1 = "=left(RC[-3],2)"

Cells(n, 7).FormulaR1C1 = "=mid(RC[-4],4,2)"

Cells(n, 8).FormulaR1C1 = "=right(RC[-5],2)"

Cells(n, 9).FormulaR1C1 = "=RC[-3]*3600+RC[-2]*60+RC[-1]"

Cells(n, 10).FormulaR1C1 = "=RC[-6]/0.75"

Cells(n, 11).Value = (Cells(2, 2).Value - Cells(n, 10).Value) * Cells(2, 4).Value

Cells(4, 13).Value = (n / nTide) * 100 'escreve a % de execução

Next n

'correspondência entre o tempo de maré e o tempo do traço

Dim Traco As Integer

Dim Contador As Integer

Ttraco = 0

Contador = 4

Sheets("Results").Select

For n = 4 To nTracos

Ttraco = Sheets("Seismic_data").Cells(n, 16).Value

For i = 4 To nTide

If Ttraco >= Sheets("Tide_data").Cells(i, 9).Value Then

If Ttraco < Sheets("Tide_data").Cells(i + 1, 9).Value Then

Contador = i

```

        Sheets("results").Cells(n, 1).Value = Sheets("Seismic_data").Cells(n, 2).Value
        Sheets("results").Cells(n, 2).Value = Sheets("Tide_data").Cells(i, 11).Value
        Sheets("results").Cells(n, 4).Value = Sheets("Tide_data").Cells(i, 10).Value
        Sheets("results").Cells(n, 5).Value = Sheets("Seismic_data").Cells(n, 16).Value
        Sheets("results").Cells(n, 6).Value = Sheets("Tide_data").Cells(i, 9).Value
        Sheets("results").Cells(n, 7).Value = Sheets("results").Cells(n, 5).Value - Sheets("results").Cells(n, 6).Value
        Sheets("results").Cells(4, 11).Value = (n / nTracos) * 100 'escreve a % de execução
    Exit For
End If
End If
Next i
'End If
Next n

'Máximos e mínimos
Sheets("Results").Select
Max = 4
Min = 4

For n = 4 To nTracos
    If Cells(n, 2).Value > Cells(Max, 2).Value Then
        Max = n
    End If

    If Cells(n, 2).Value <= Cells(Min, 2).Value Then
        Min = n
    End If
Next n
'Max
Cells(7, 9).Value = Cells(Max, 1).Value
Cells(7, 10).Value = Cells(Max, 2).Value
Cells(7, 11).Value = Cells(Max, 4).Value
Cells(7, 12).Value = Cells(Max, 4).Value * 0.75
'Min
Cells(8, 9).Value = Cells(Min, 1).Value
Cells(8, 10).Value = Cells(Min, 2).Value
Cells(8, 11).Value = Cells(Min, 4).Value
Cells(8, 12).Value = Cells(Min, 4).Value * 0.75
'Dif
Cells(9, 10).Value = Cells(7, 10).Value - Cells(8, 10).Value
Cells(9, 11).Value = Cells(7, 11).Value - Cells(8, 11).Value
Cells(9, 12).Value = Cells(7, 12).Value - Cells(8, 12).Value

End Sub

Sub Grafico_1()

Sheets("Results").Activate
    Range("A:A,B:B").Select
    Range("A4").Activate

    'criação do gráfico
    Dim chLayback As ChartObject

'Define a área onde vai criar o gráfico (distanciax,distanciay,comprimento, altura)
Set chLayback = Sheets("Results").ChartObjects.Add(600, 20, 300, 170)

'Define o tipo de gráfico e cria-o, e define algumas das suas características
chLayback.Chart.ChartType = xlXYScatterLinesNoMarkers 'xlXYScatterLines
chLayback.Chart.SetSourceData Source:=Sheets("Results").Range( _
    "A:A,B:B"), PlotBy:=xlColumns

With chLayback.Chart
    .HasTitle = True
    .HasLegend = False
    .ChartTitle.Characters.Text = "Tide Correction"
    .Axes(xlCategory, xlPrimary).HasTitle = True

```

```
.Axes(xlCategory, xlPrimary).AxisTitle.Characters.Text = "Trace number"
.Axes(xlValue, xlPrimary).HasTitle = True
.Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "Tide correction (ms, twt)"
.PlotArea.ClearFormats
End With

End Sub

Sub Grafico_2()

Sheets("Results").Activate
Range("A:A,G:G").Select
Range("A4").Activate

'criação do gráfico
Dim chLayback As ChartObject

'Define a área onde vai criar o gráfico (distanciax,distanciay,comprimento, altura)
Set chLayback = Sheets("Results").ChartObjects.Add(600, 190, 300, 170)

'Define o tipo de gráfico e cria-o, e define algumas das suas características
chLayback.Chart.ChartType = xlXYScatterLinesNoMarkers 'xlXYScatterLines
chLayback.Chart.SetSourceData Source:=Sheets("Results").Range( _
    "A:A,G:G"), PlotBy:=xlColumns

With chLayback.Chart
.HasTitle = True
.HasLegend = False
.ChartTitle.Characters.Text = "Time Differences"
.Axes(xlCategory, xlPrimary).HasTitle = True
.Axes(xlCategory, xlPrimary).AxisTitle.Characters.Text = "Trace number"
.Axes(xlValue, xlPrimary).HasTitle = True
.Axes(xlValue, xlPrimary).AxisTitle.Characters.Text = "Time differences (s)"
.PlotArea.ClearFormats
End With

End Sub

Sub Run()

Corr_Mare
Grafico_2
Grafico_1
Beep

End Sub
```