

MICROSEISMIC NETWORK

INSTALLATION

for

SEISMIC TOMOGRAPHY APPLICATIONS

Updated 2017

INTRODUCTION

This report presents the general principles of the installation of a microseismic network and acquisition of raw data, followed during the Seismic Tomography survey. Describes the installation of a typical seismic station.

A typical micro-seismic network, consisted of about 70 - 80 seismic stations is usually installed in the region of the block. Additionally some seismic stations can be placed in the wider area of the block, thus covering larger area.



Figure 1: A micro seismic network example.

MICROSEISMIC NETWORK INSTALLATION

The installation of a microseismic network for seismic tomographic surveying, consists of 4 distinctive steps:

- 1. *SITE SELECTION***
- 2. *DRILLING AND BOREHOLE CONSTRUCTION***
- 3. *SEISMIC STATION CONSTRUCTION***
- 4. *INSTALLATION OF EQUIPMENT***

This procedure is followed at every project with only minor deviations, in an attempt to match particular local conditions and prerequisites prevailing in the area of the survey. Accessibility of the survey area is usually one of the main problems where in some cases transportation has to be done only using 4x4 cars, boats and only through the rivers or lakes, where in some cases, problems like low tide and/or fallen trees provide much difficulty of accessing the sites. In some other cases, that the road network is not in good condition may cause un-accessibilities to some stations due damages especially at wintertime.

SITE SELECTION

The implementation of the in-desk designed network and its precise in-field location, with an in-parallel view of the prevailing on-site conditions, restrictions and limitations is the overall process of the site selection.

In every project the designed network is transferred to the survey region together with the following considerations:

- a) The minimum possible displacement of the station from its initial coordinates as determined in the in-desk design
- b) The elimination of environmental noises that could interfere in the recordings. Such sources of noise usually are the very high plantation, nearby roads, residential noise etc
- c) Any river water flow.
- d) The traffic from the roads, where in some cases it is trivial, but in some other cases like the main traffic roads, it is significant.
- e) Possible noise from close factories
- f) The security of the station and the installed equipment

For all the above reasons, plus that the quality of the soil may be not good in some cases we place the sensors into boreholes of 15-18m depth while in some other palaces, even 2m depth will be enough (rocky terrain).

When the site is, finally, selected, we record its coordinates and altitude and mark it on the map with a hand-held GPS unit. Its final and accurate positioning will be successively determined by the in-built GPS of each seismograph. The coordinates are monitored into the instrument's position file.

During the network operation, each station is inspected for verifying that the surrounding conditions remain stable and as evaluated during the selection.

DRILLING AND BOREHOLE CONSTRUCTION

Once the sites have been selected and fixed, we proceed with the drilling and construction of the borehole where the seismic sensor will be installed. The drilling depth and the precise installation of the sensor depend generally on the type of subsoil in the survey area. The less homogeneous and coherent the soil is, the greater the drilling and installation depth should be, down to a usual 18-20m, which is regarded as substantial in minimizing interferences to the recorded signal.

Drilling

The basic requirement when drilling a PST borehole is to reach a homogeneous and coherent to semi-rigid subsoil formation, having good coupling to the installed borehole sensor, aiming in the best possible recording of seismic waves with the lowest attenuation and noise interference. Talking about areas with soft subsoil, the drilling depth of all the sites will be 18 meters but it may be deeper if required.

Several drilling machine types being used like portable, gasoline powered, drilling machines. Some may be disassembled in parts for easy transportation (fig2). In cases that the soil is muddy, we use a water pump, which could supply water into the drilling tubes. The drilling tubes operate by hand in order to reach the depth of 18 meters.

Borehole construction

Each borehole requires a casing and a uniform cementation in order to achieve the best possible coupling of the borehole sensor and casing to the surrounding subsoil strata. The station vault will be then constructed around the protruding top of the casing, to accommodate the recording equipment.

We use a 82mm plastic tube as casing (Fig. 4), with its lower end sealed to prevent any bottom lying materials from entering the tube. Prior to the cementation of the borehole, the tube is adjusted to a precisely vertical position (Fig.5) Almost 5-7 pipes of 3m length each are successively connected form the casing which was lowered within the borehole (Fig. 6). All pipes are linked to one another using PVC glue, silicon sealant and heavy-duty adhesive tape as wrapping agent, while the first pipe had also a bottom lid to prevent drilling debris from entering the casing.



Fig. 2: Portable Drilling Machine



Fig. 3: Small Drilling Machine



Fig.4: Inclinometer tubes



Fig.5: Vertical orientation

The cementation (grouting) is done with the appropriate cement grout poured into the free space between the borehole walls and the tube casing (Fig. 6). During the cementation, the casing is displaced vertically several times to facilitate the gradual settlement of the heavier grout down to the bottom of the borehole and the entire extrusion of lighter water, until we achieve an almost homogenous cement volume surrounding the casing.



Fig.6: Cementation of the borehole

When the column is filled up with the grout, the casing is checked again for any deviation from the vertical axis (Fig. 5).

When the installation is taking place in swamp areas, above the top of the finished and cemented borehole, the construction of a seismic station basis is taking place, to put the seismic vault over it (plastic drum) where the instruments and equipment will be securely locked (Fig. 7).

When the installation is taking place in mountainous terrains, where generally the ground is stable and there is no ant risk of flood, we construct the seismic vault based on the ground and we keep the top of the borehole into the vault.



Fig.7: Station housing



Fig.8: Station Vault



Fig.9: Finished Station Vault



Fig.10: Station Vault Construction

The construction method described so far, is followed without exception for all seismic stations.

INSTALLATION OF EQUIPMENT

Equipment can be installed in each station vault after a 3 days interval, necessary for the hardening of the cement. The basic requirement for the installation of a borehole seismic sensor is the very good coupling of the sensor with the casing walls which, in the meantime of the 3 - 5 days dry-up period, have formed a unique set with the cement and the surrounding subsoil.

There is a variety of methods for achieving correct coupling, among which the utilization of a packer is the most frequent one. GEObit sensors provide smart elastic packer (Fig. 11) that strongly press the sensor to the walls of the casing and in parallel allows the easy un-installation (GEObit patent). A metallic wire is attached at the upper part of the packer from where the sensor is pulled-out. The wired sensor and the packer are then placed within the tube, facing North, with the aid of the orientation dot on the cap housing of the sensor and using an external compass

When the sensor is inserted in the borehole casing, the packer is laterally compressed and holds the sensor with the casing tubes. The standard angular shape of packer is used in all boreholes safeguards that all sensors are subject to an equal pressure, hence having an equally good coupling to their borehole casings. With the technique of the angular packer we eliminate the variations in the sensor coupling, occurring when shaping packers manually, from an aluminum tube.



Fig.11: Sensor with packer

All displacements of the sensor within the tube casing should apply no tension to the electric cable, so the sensor is tied up with a steel wire for pulling, driven through a hole at the top of the packer.

Once the sensor is placed within the casing tube facing north, it should be lowered down to the bottom slowly so as to maintain its correct orientation. Lowering is done by using rods of thin plastic tube interconnected to one another until we reach the desired depth (Fig. 12). For deeper installations we support guiding wheels for lowering the sensor and keep it oriented and vertical. When the sensor is at its final position, we withdraw the rods, accommodate the remaining electric cable and sensor wire, and we are ready to install the recorder.



Fig.12:Pipes connection



Fig.13: Seismograph SRI32L

The datalogger is connected directly to the sensor, to the GPS antenna and to the power source (a 12V/65Ah DC battery) previously placed in the vault. Finally, the station is on-site inspected for correct signal reception (Fig. 15).



Fig.14: SRi32L seismograph

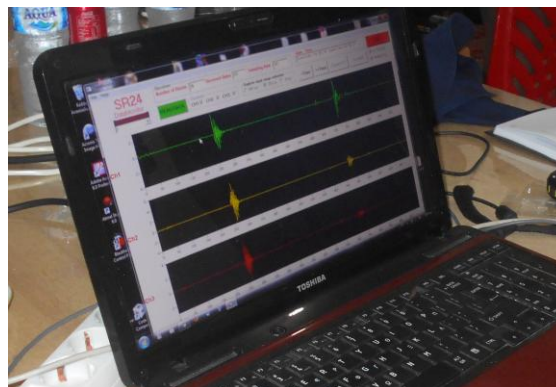


Fig.15: On-site inspection

REAL-TIME TEST OF THE RECORDED SIGNAL

Once the seismic station has been installed, and all the connections have been checked, the station is powered on. The operator has to verify proper operation just getting informed from the messages being plotted on the LCD (Fig. 14). Information about microSD Card, initialization file (recording parameters), battery voltage, GPS status, and sensor operation are alternatively being plotted on the LCD screen.



Fig.16: SRi32L seismograph check



Fig.17: On-site inspection

The recording parameters for all the stations are (here datalogger is "L" type which means that the data are stored locally, into the removable microSD card):

Data Structure =WAVE_DATA_FILES;

Station ID =001;

Sampling Rate =100; [samples/sec]

FIR Phase Response =MINIMUM;

Channels =3;

Gain =1;

File Duration =10; [min]

Delete Old Files =0;

Log File Size =400; [Kbytes]

GPS Cycle =60; [min]

Serial Data Port =ENABLED;

Data Baud Rate =115200; [bits/sec]

If the test that made from the recorder itself is successful, then it proceeds with the acquisition. When acquisition has been started, the data files are recorded in the flash card, organized in directories as it is described below (see "Form Of The Data") . In parallel, the real time data stream is available on the serial port so the operator can easily monitor it using a laptop running "DATAMONITOR" or "LiveSeis" software.

Using DATAMONITOR the operator can verify proper sensor & digitizer operation. If everything is running well, the operator must do a test of simulation of a seismic event to verify proper sensor recording. This is done using a dropping weight from a constant height and direction. The dropping weight is dropped from 1m height, and from directions North & East, and from a fixed distance 10 meters from the borehole of the sensor.



Fig.18: Testing with the dropping weight

With this test the operator can verify proper function of several recording parameters in real time, before he stores the record for afterwards post processing in office.

The testing parameters are:

- Test the signal amplitude and shape of the vertical component.
- Test signal amplitude & shape of the N-S component when the weight is dropped in North Direction.
- Test signal amplitude & shape of the E-W component when the weight is dropped in East Direction.
- Sensitivity test.
- Overall sensor contact and well quality check.

Once the test is successful, the operator switches off the recorder, and takes the flash card for further post processing. Then he puts a new flash card, switches on, and leaves the recorder in operation.

IMPORTANT NOTE: All the seismological equipment are pre-calibrated before they deployment for operation.

POST PROCESSING OF THE RECORDED TEST SIGNAL

Further signal analysis is done at the base's camp office, after the seismic crew is back. The flash card which contains the data of the test of each station, has to be detailed processed and analyzed.

The field engineer has to verify proper sensor operation, check signal amplitude on Vertical, N-S & E-W component, sensitivity, and signal spectrum analysis. This detailed test is to double confirm the proper operation of the seismic station.

Further processing and final check of the proper operation of each station will be done from the field engineer, after retrieving the first data, where the whole day's records will be available, and there will be the ability to check the recordings of some seismic events.

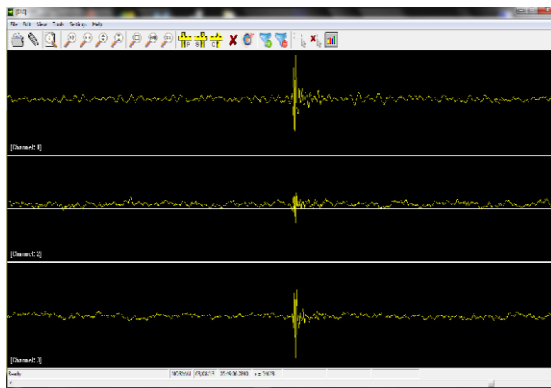


Fig.19: Dropping Weight Signal E-W

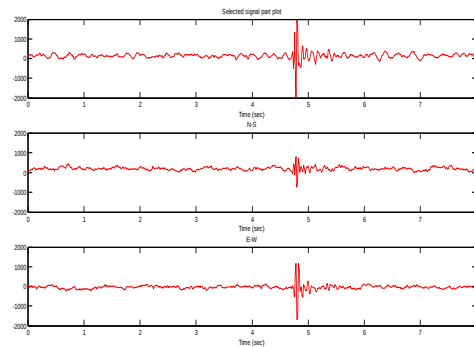


Fig.20: Processing in Matlab

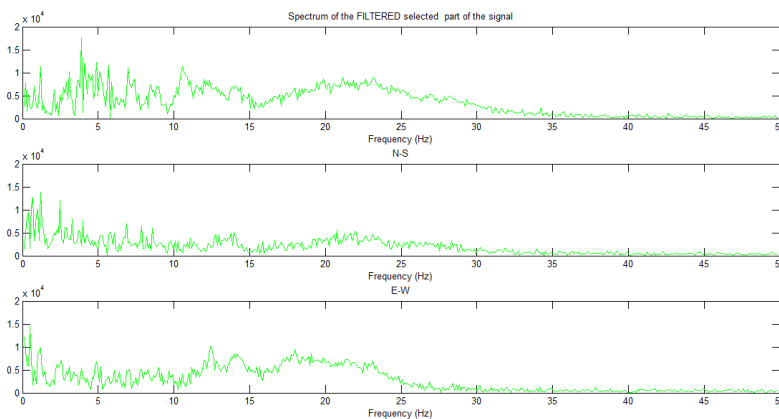


Fig.21: Signal Spectrum Analysis

NETWORK OPERATION & RAW DATA ACQUISITION

Any seismic tomography survey will be comprising the following 3 distinctive steps:

- 1. NETWORK SERVICING, TECHNICAL SUPPORT AND REPORTING**
- 2. DATA COLLECTION**
- 3. EVALUATION & ANALYSIS OF RECORDINGS**
- 4. DATA QUALITY CONTROL**

NETWORK SERVICING, TECHNICAL SUPPORT AND REPORTING

Concerning the equipment installed in each station, the power source (12V/55Ah rechargeable battery) has an estimated capacity of 40 days of continuous supply, and the storage device (memory card 8GB) a capacity of more than three months of free recordable space. Consequently, all scheduled activities related to the network servicing and data acquisition are based on a fixed program of calls, repeated on a 15-20 days cycle. The approximately two weeks time-span is usually chosen to assure that every battery will be kept alive until the next visit, so no data will be lost.

All stations of the installed network are sorted into different itineraries according to their geographical location and all itineraries are allocated to the service crew. In doing so, we obtain a periodic plan with 7 days of active network servicing for two service teams, plus 7 days off (Fig.22). Normally, those 7 days off are added at the end of the weekly plan and are available for:

- Regular break for the operators.

- Displacement of any working day in case an unpredicted incident prevented us from working during that specific date.
- On site call(s) to one or more stations, realized by our field manager, for inspection of the station (if necessary) or repair of any technical problem arising during the week.
- Completion of one or more calls which were normally scheduled during the working days but for some particular reason (i.e. time delay, road conditions, accidental reasons, etc) were not realized.

A typical periodic schedule is presented as example at Fig. 22 which is following during the entire duration of the project, with only minor modifications.

STATION CALLS PROGRAMME		
DAY	ROUTES	
1	Route E: 35 – 46 – 56	Crew 1
2	Route A: 04 – 05 – 17 – 18 – 29 – 30	Crew 1
	Route M: 08 – 07 – 06 – 31 – 20 – 19 – 32	Crew 2
3	Route B: 03 – 15 – 16 – 28 – 40 – 41	Crew 1
	Route J: 14 – 01 – 02	Crew 2
4	Route N: 09 – 21 – 23 – 22 – 34 – 33 – 45	Crew 1
	Route K: 12 – 11 – 24 – 36 – 25 – 10	Crew 2
5	Route F: 42 – 43 – 54 – 44 – 55 – 57	Crew 1
6	Route C: 26 – 27 – 38 – 39 – 50 – 49	Crew 1
7	Route D: 61 – 62 – 63 – 51 – 52 – 64 – 53	Crew 1
	Route G: 37 – 38 – 47 – 70 – 60 – 59 – 58	Crew 2
8 - 15	Days Off / possible repairs	

Fig.22: Periodic servicing schedule

Modifications and adaptations of the periodic service program may be done, whenever necessary, to cope with actual obstacles to the planned activity.

The standard procedure in the network servicing involves the following activities:

- Replacement of the power source (12V rechargeable batteries)
- Replacement of the data storage media (microSD of 8 GB volume)
- Regular external and internal control and maintenance (cleaning of condensations, regular use of insecticides, lubrication of rusted parts, etc)
- Occasional real-time control of signal reception
- On-demand servicing of installed equipment once an unexpected technical problem arouses (replacement of power cable, on-site repair of the recorder, replacement of the recorder, etc.)

Raw data recorded by each seismograph, are stored in the memory card. Every day, all memory cards collected through the scheduled stations were received in our base camp office where the back-up and preliminary evaluation is done, as presented right below.

SEISMIC CREW - EQUIPMENT

For the servicing of the stations, it is necessary to create two or more standard groups consisting of specialized personnel, workers, and an appropriate boat depending the route that has to be followed. Transportations in the survey area is able to be done trough the rivers, using speed or long boats, or by roads using 4X4 jeeps. It is extremely necessary all the crews be back in base camp before sunset in each case.

The seismic crew is consisted of the following personnel:

- The operator – servicing the station
- The worker – equipment / batteries transportation
- The bodyguard - safety
- The driver



Fig.23: Cab car in operation

FORM OF RAW DATA

Each removable memory card includes 3 files.

File ini.txt is the file containing the acquisition parameters of the station [Sampling rate 100 samples/sec, files of 10 minutes each, a log file of 400 KB, 3 recording channels, GPS power cycle every 60 min. and station number (name) ID 001]

Data Structure =WAVE_DATA_FILES;

Station ID =001;

Sampling Rate =100; [samples/sec]

FIR Phase Response =MINIMUM;

Channels =3;

Gain =1;

File Duration =10; [min]

Delete Old Files =0;

Log File Size =400; [Kbytes]

GPS Cycle =60; [min]

Serial Data Port =ENABLED;

Data Baud Rate =115200; [bits/sec]

Folders CONTROL and Folder DATA (Fig. 24)

CONTROL	1/1/2000 12:00 πμ	File folder	
DATA	1/1/2000 12:00 πμ	File folder	
INL.TXT	1/1/2000 12:00 πμ	Text Document	1 KB

Type: Text Document
Size: 305 bytes

Fig. 24: Folders included in each memory card

Folder CONTROL includes file position and file logfile (Fig. 25)

Name	Date modified	Type	Size
LOG.TXT	2/1/2000 5:40 μμ	Text Document	18 KB
POS.TXT	1/1/2000 12:00 πμ	Text Document	1 KB

Fig. 25: Files included in the folder CONTROL

file position includes the station coordinates as detected by the in-built GPS (Fig. 26),

file logfile includes a continuous logging of the operating conditions and activities of the datalogger (Fig. 27)

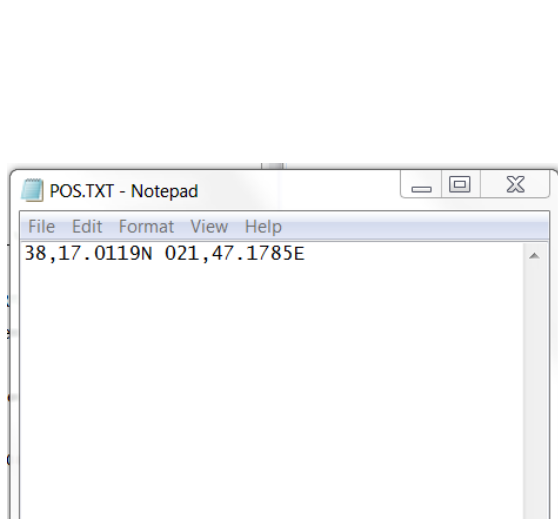


Fig. 26: Station coordinates

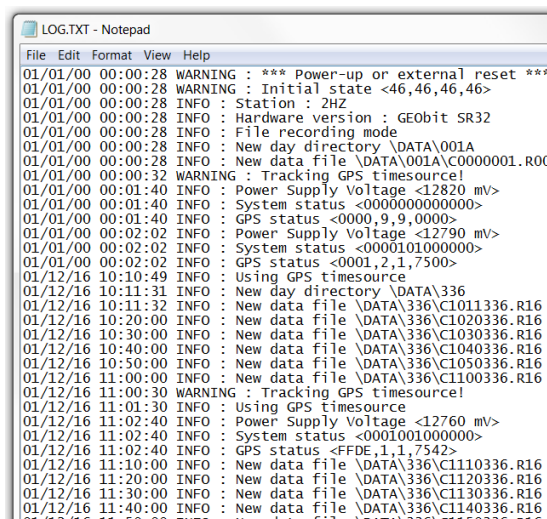


Fig. 27: Activity log for the recording

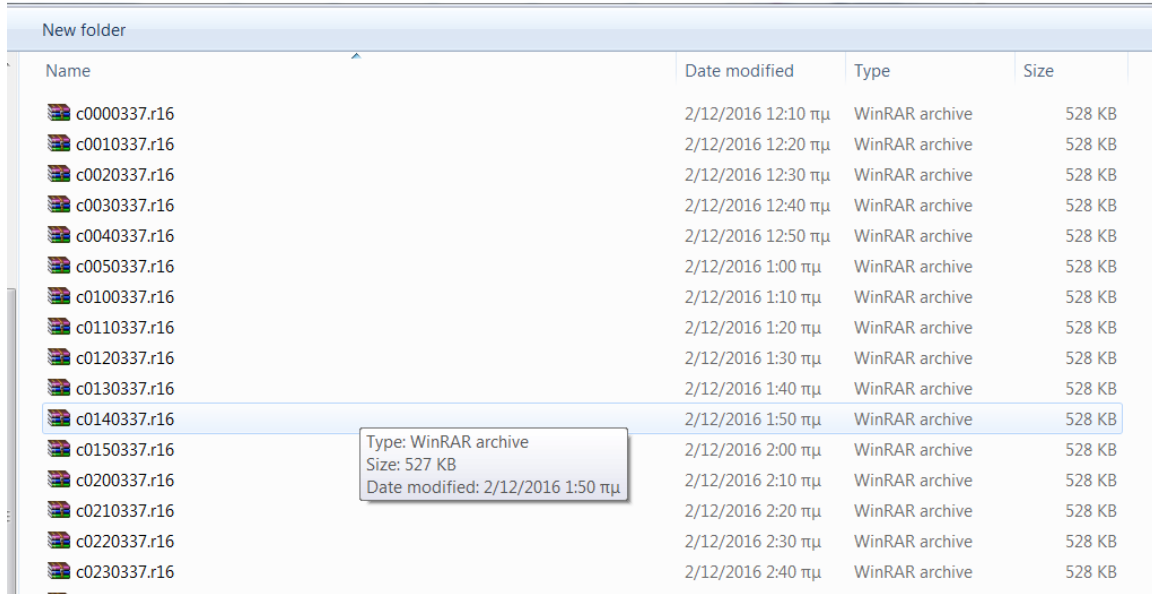
Folder DATA includes numerical files representing Julian calendar days (Fig. 28)

Name	Date modified	Type	Size
001A	9/3/2017 7:20 μμ	File folder	
336	9/3/2017 7:20 μμ	File folder	
337	9/3/2017 7:20 μμ	File folder	
338	9/3/2017 7:20 μμ	File folder	
339	9/3/2017 7:20 μμ	File folder	

Fig. 28: Sequence of Julian Calendar days recorded

When a datalogger is turned ON, and after completion of the initial set-up, it automatically creates the **logfile**, where all further activities will be recorded and stored. Once the internal GPS has been synchronized with the UTC time, it creates the **position** file, where the precise coordinates of the station are stored, as verified through the SAT connection, as well as the initial file 001A. In the next stage, it creates a new file under semi-compressed format CORE-32, where the continuous recordings of all 3 channels are stored. Every 10 minutes, a new file is created and the procedure starts over again, thus building gradually a sequence of 10-minute files belonging to the same calendar

day (i.e. file 0110209 includes the recording from 01:10:00 hours to 01:19:59 hours of day 209) (Fig. 29). All files of the same day are stored in the same folder, denoted by the respective Julian Calendar day numbering.



Name	Date modified	Type	Size
c0000337.r16	2/12/2016 12:10 πμ	WinRAR archive	528 KB
c0010337.r16	2/12/2016 12:20 πμ	WinRAR archive	528 KB
c0020337.r16	2/12/2016 12:30 πμ	WinRAR archive	528 KB
c0030337.r16	2/12/2016 12:40 πμ	WinRAR archive	528 KB
c0040337.r16	2/12/2016 12:50 πμ	WinRAR archive	528 KB
c0050337.r16	2/12/2016 1:00 πμ	WinRAR archive	528 KB
c0100337.r16	2/12/2016 1:10 πμ	WinRAR archive	528 KB
c0110337.r16	2/12/2016 1:20 πμ	WinRAR archive	528 KB
c0120337.r16	2/12/2016 1:30 πμ	WinRAR archive	528 KB
c0130337.r16	2/12/2016 1:40 πμ	WinRAR archive	528 KB
c0140337.r16	2/12/2016 1:50 πμ	WinRAR archive	528 KB
c0150337.r16	2/12/2016 2:00 πμ	WinRAR archive	528 KB
c0200337.r16	2/12/2016 2:10 πμ	WinRAR archive	528 KB
c0210337.r16	2/12/2016 2:20 πμ	WinRAR archive	528 KB
c0220337.r16	2/12/2016 2:30 πμ	WinRAR archive	528 KB
c0230337.r16	2/12/2016 2:40 πμ	WinRAR archive	528 KB

Fig. 29: Sequence of successive 10-minute zipped files with the actual seismic recordings of the seismograph

Memory cards from all stations are collected and stored in successive folders, named after the relevant station ID

REAL-TIME CONTROL OF SIGNAL RECEPTION

Real-time control might be performed on-site by our field manager either

- As an occasional or ad-hoc inspection of one or more stations randomly selected, or
- Following an acknowledged malfunctioning of a particular station, traced after the preliminary evaluation of the incoming raw data

The real-time control of signal reception is done by on-line connection of the seismograph installed and with the relevant software DATAMONITOR (Fig. 30)

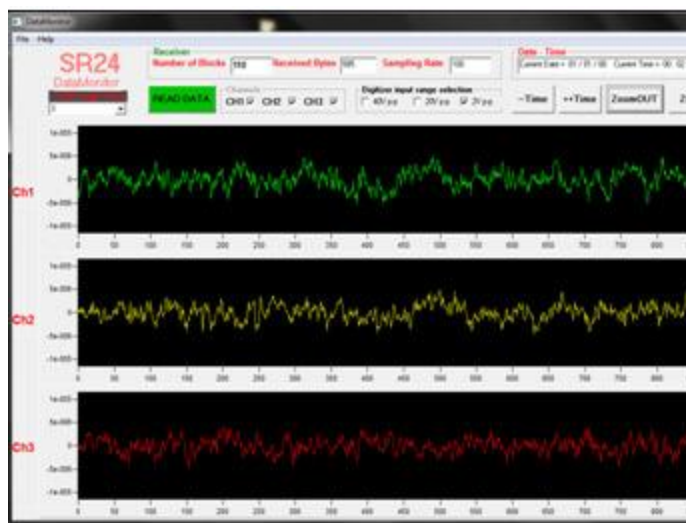


Fig. 30: Datamonitor

If any malfunctioning is traced, our field manager has the option of resolving the problem through on-site repair or (if this is impossible) to replace immediately the seismograph with a spare one, and bring the initially installed back to our base for a thorough service.

PRELIMINARY EVALUATION OF RECORDED DATA

Data recorded and stored in memory cards, after their routine back-up, are subject to a preliminary evaluation. This first quick view has two different targets:

- We verify that all 3 channels are recording regularly and without any undesired interferences
- We make a quick check for the presence of clearly noticeable seismic events

The preliminary evaluation is done with the aid of HELICORDER and DATAVIEWER software. HELICORDER presents the entire set of the 10-minute files recorded in one day, so as to have a first view of the daily activity in the station and the quality of the recordings. We also use it to pinpoint possible seismic events as they appear at first sight and to transfer them to a DATAVIEWER for a further, more detailed checking. (Fig. 31)

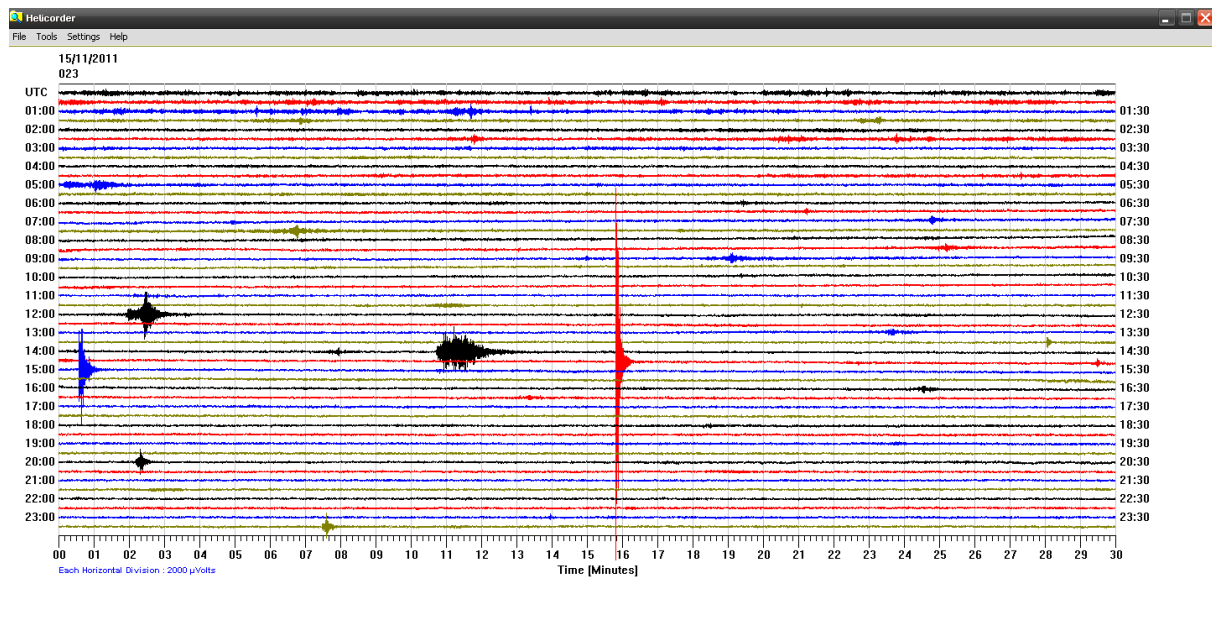


Fig. 31: HELICORDER showing all day record.

Once a certain day is loaded in HELICORDER, we can select any signal mark for further inspection through DATAVIEWER (Fig. 32)

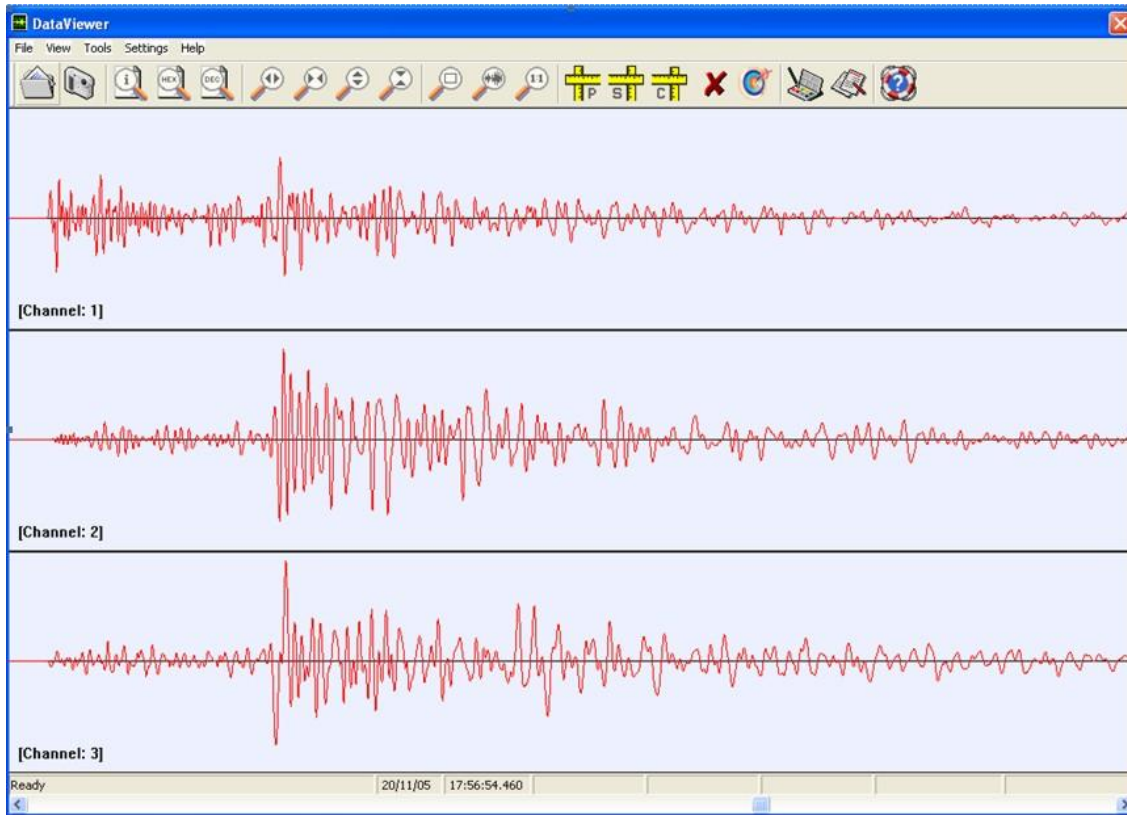


Fig. 32: DATAVIEWER shows that all 3 channels are recording regularly