National Civil Protection Department
(Seismic Survey Office)

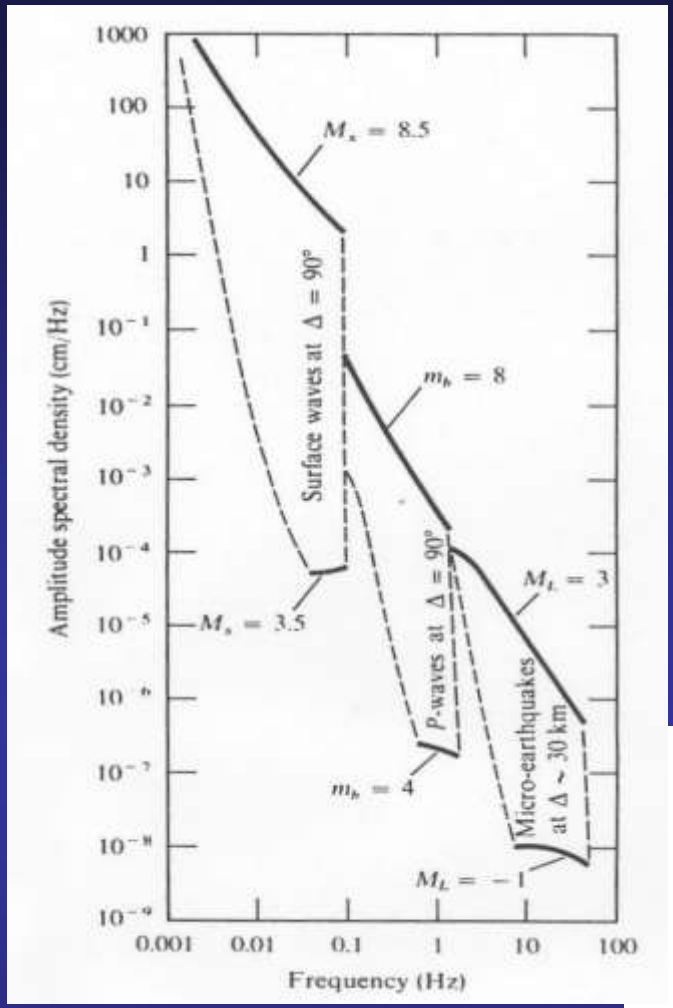
National Institute of Nuclear Physics *(INFN)*
Gran Sasso National Laboratory *(LNGS)*
(ERMES Experiment)

ET: ***Underground Seismic Array and Seismic Noise***

Gaetano De Luca

ET – WP1 meeting
LNGS – Italy, February 09th, 2009

(Ver. February 2009)



two peaks:
~ 0.14 Hz and ~ 0.07 Hz

QUANTITATIVE SEISMOLOGY
Theory and Methods

VOLUME I

Keiiti Aki
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Paul G. Richards
COLUMBIA UNIVERSITY

W. H. FREEMAN AND COMPANY
SAN FRANCISCO

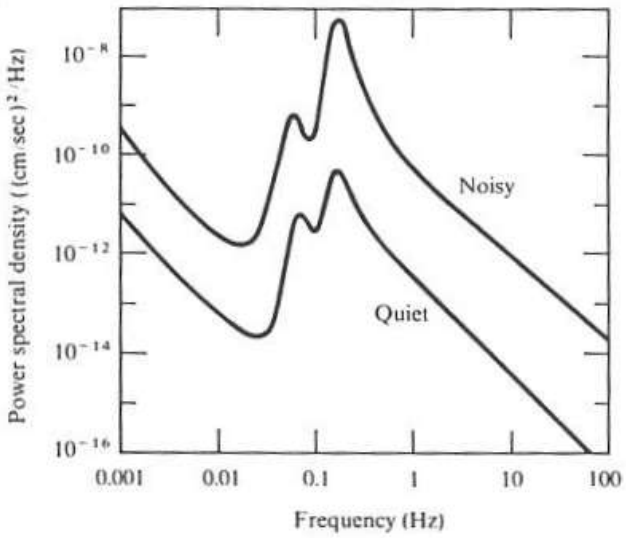
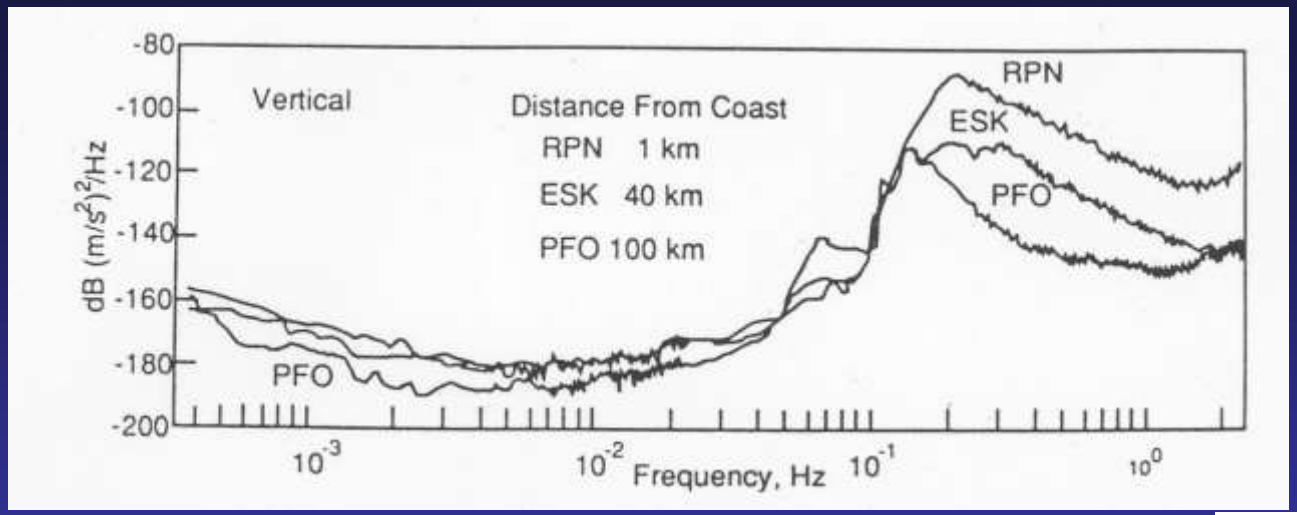
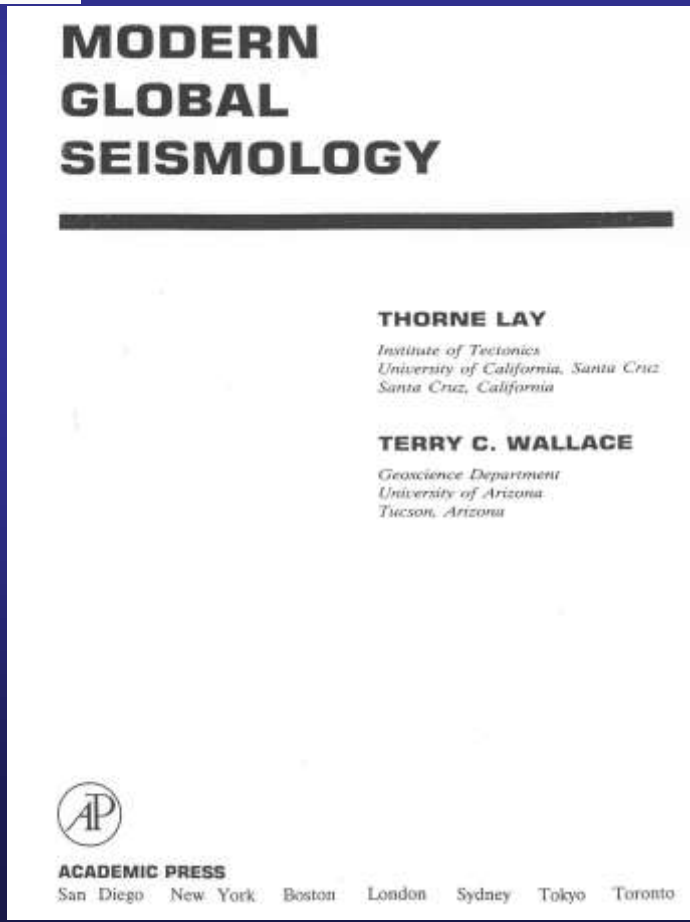


FIGURE **10.11**
Power spectra of ambient seismic noise at noisy and quiet conditions for a typical station on hard basement rock.



… background noise level is temporally and spatially variable and is not uniform at all frequencies …



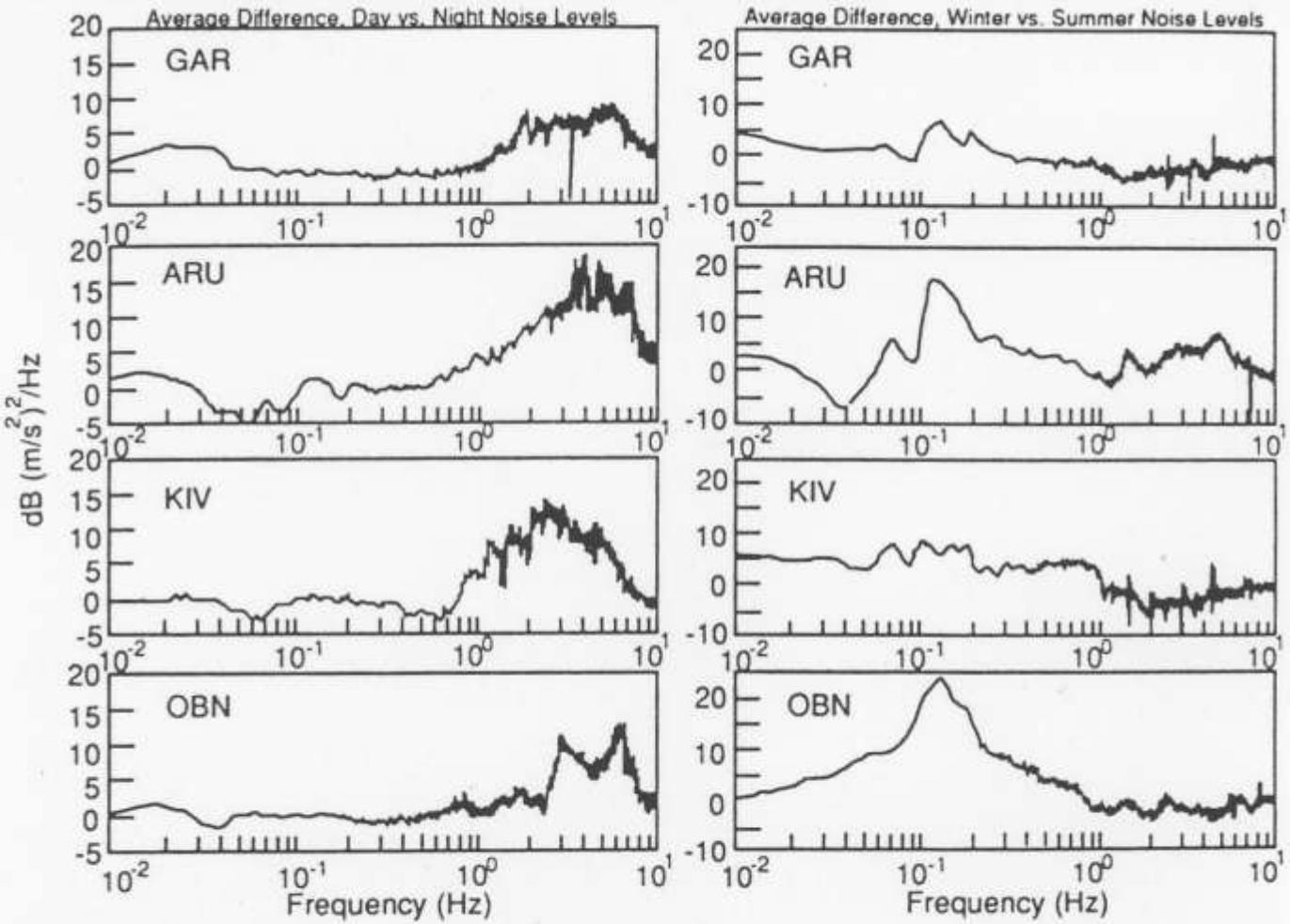
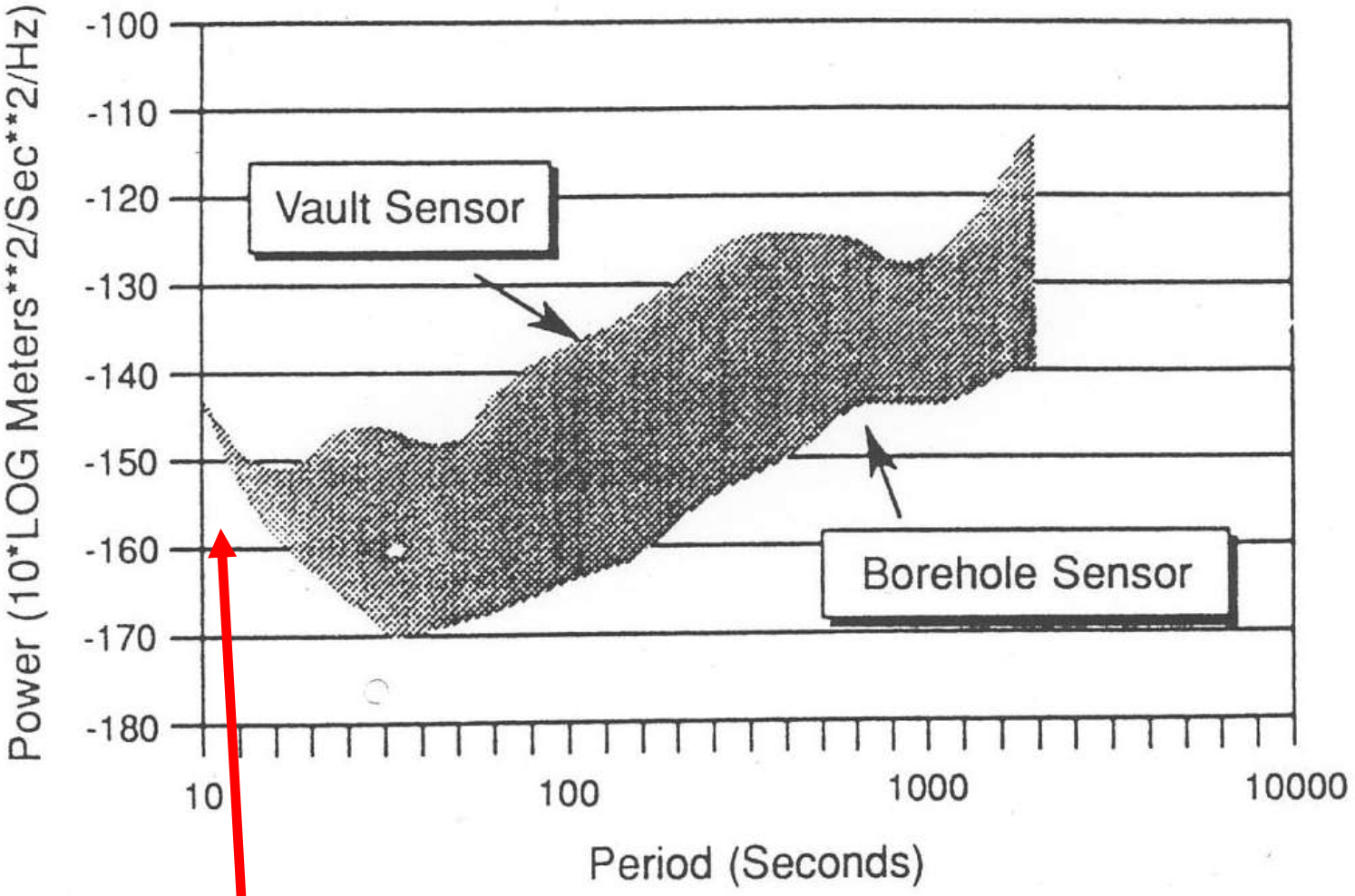
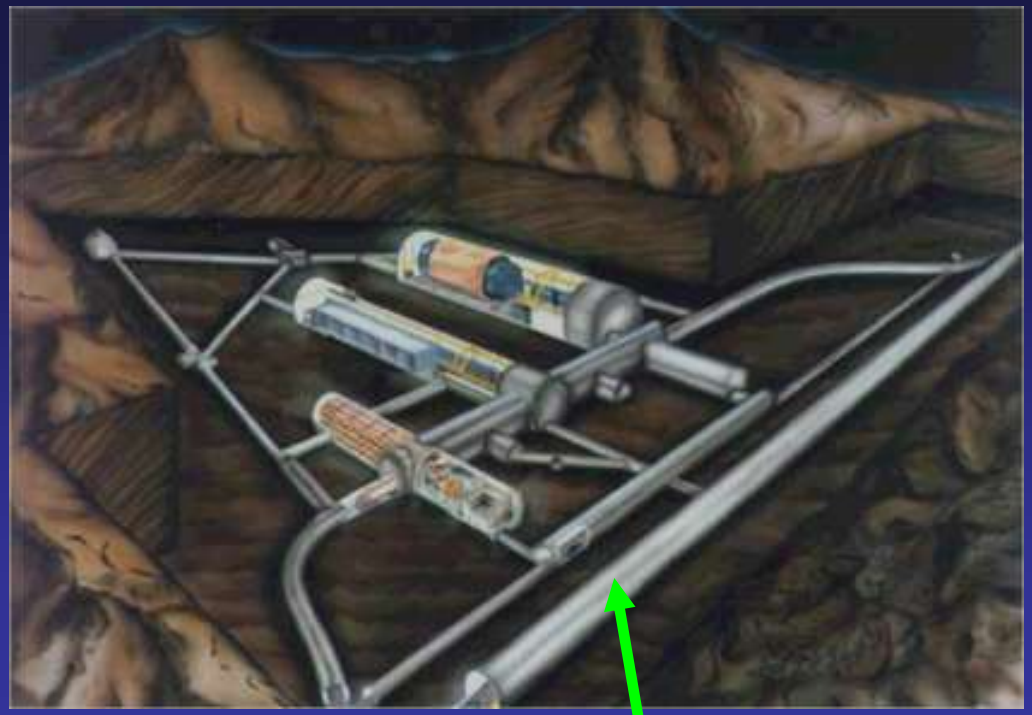
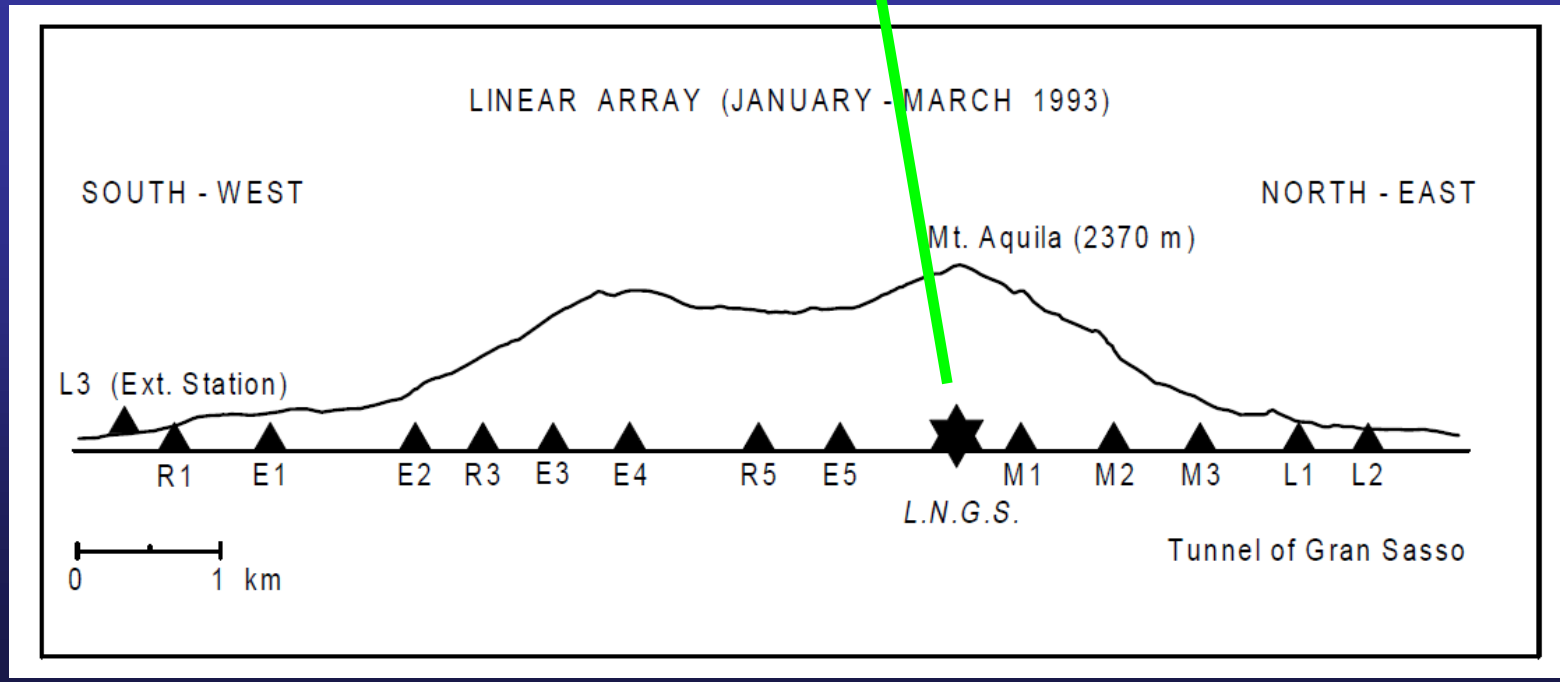


FIGURE 5.4 Differences in ground-acceleration power spectra at four stations located in the former Soviet Union between day and night (left) and winter versus summer (right). The vertical units are decibels, with 20 dB corresponding to a factor of 10 variation in ground acceleration noise level. (From Given, 1990.)


Power (10*LOG Meters**2/Sec**2/Hz)
-100
-110
-120
-130
-140
-150
-160
-170
-180
Vault Sensor
Borehole Sensor
10
100
1000
10000
Period (Seconds)




LINEAR ARRAY (JANUARY - MARCH 1993)
SOUTH - WEST
NORTH - EAST
Mt. Aquila (2370 m)
L3 (Ext. Station)
R1
E1
E2
R3
E3
E4
R5
E5
M1
M2
M3
L1
L2
L.N.G.S.
Tunnel of Gran Sasso
0
1 km

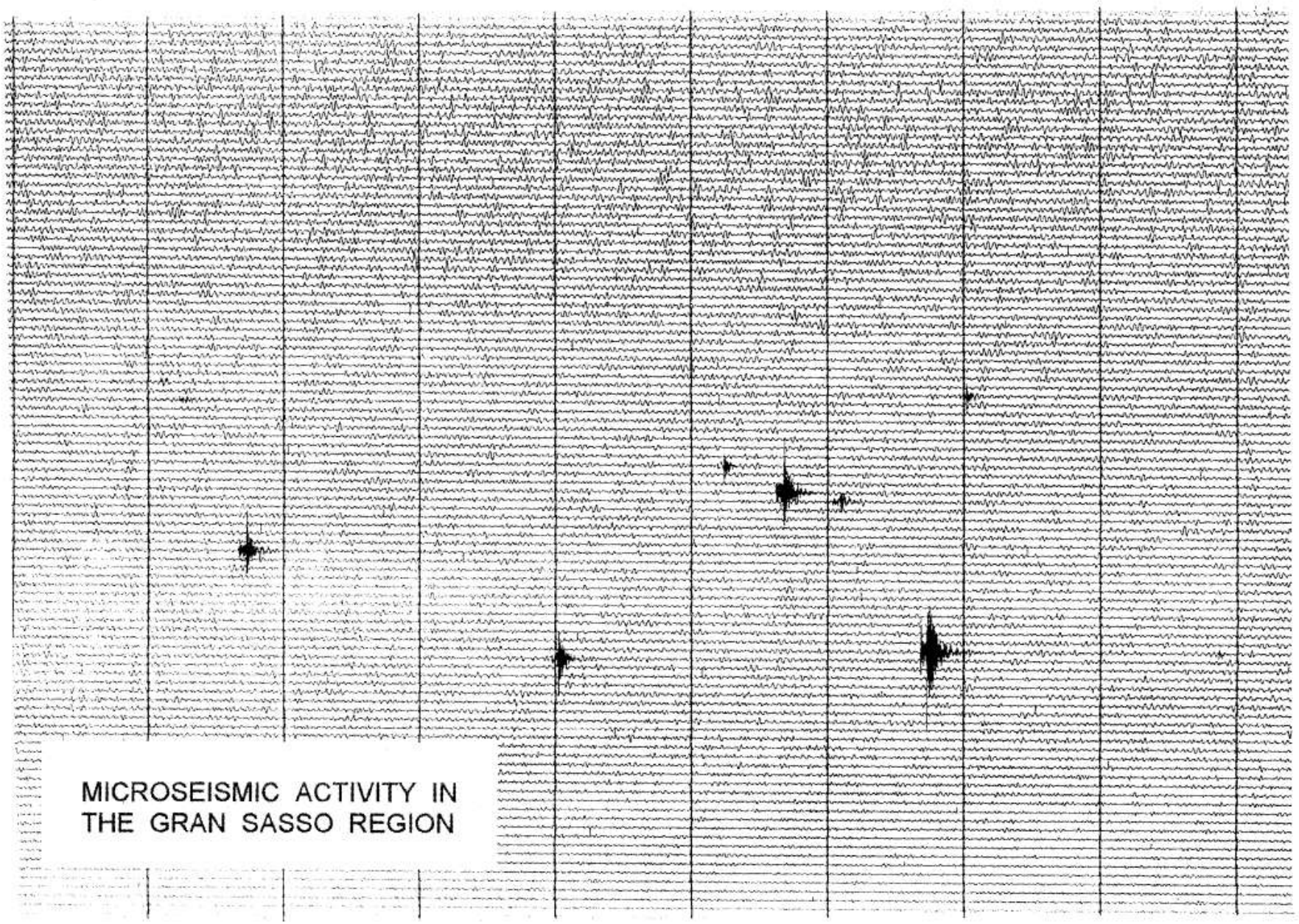


Fig. 1. Example of a drum record of microseismic activity at the end of February, 1992 in the Gran Sasso region.

De Luca G. et al. (1998). The density of the rock covering Gran Sasso Laboratories in Central Apennines, Italy by underground gravity measurements. *Journal of Applied Geophysics* **39**, 25-33.

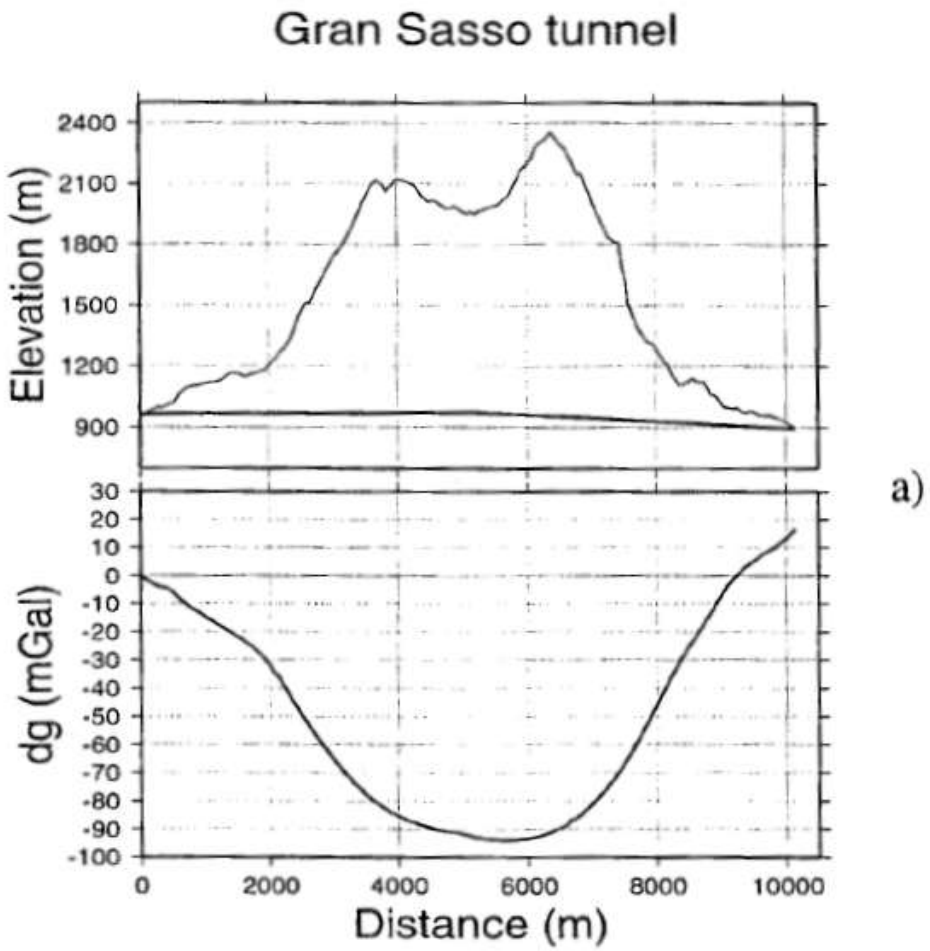
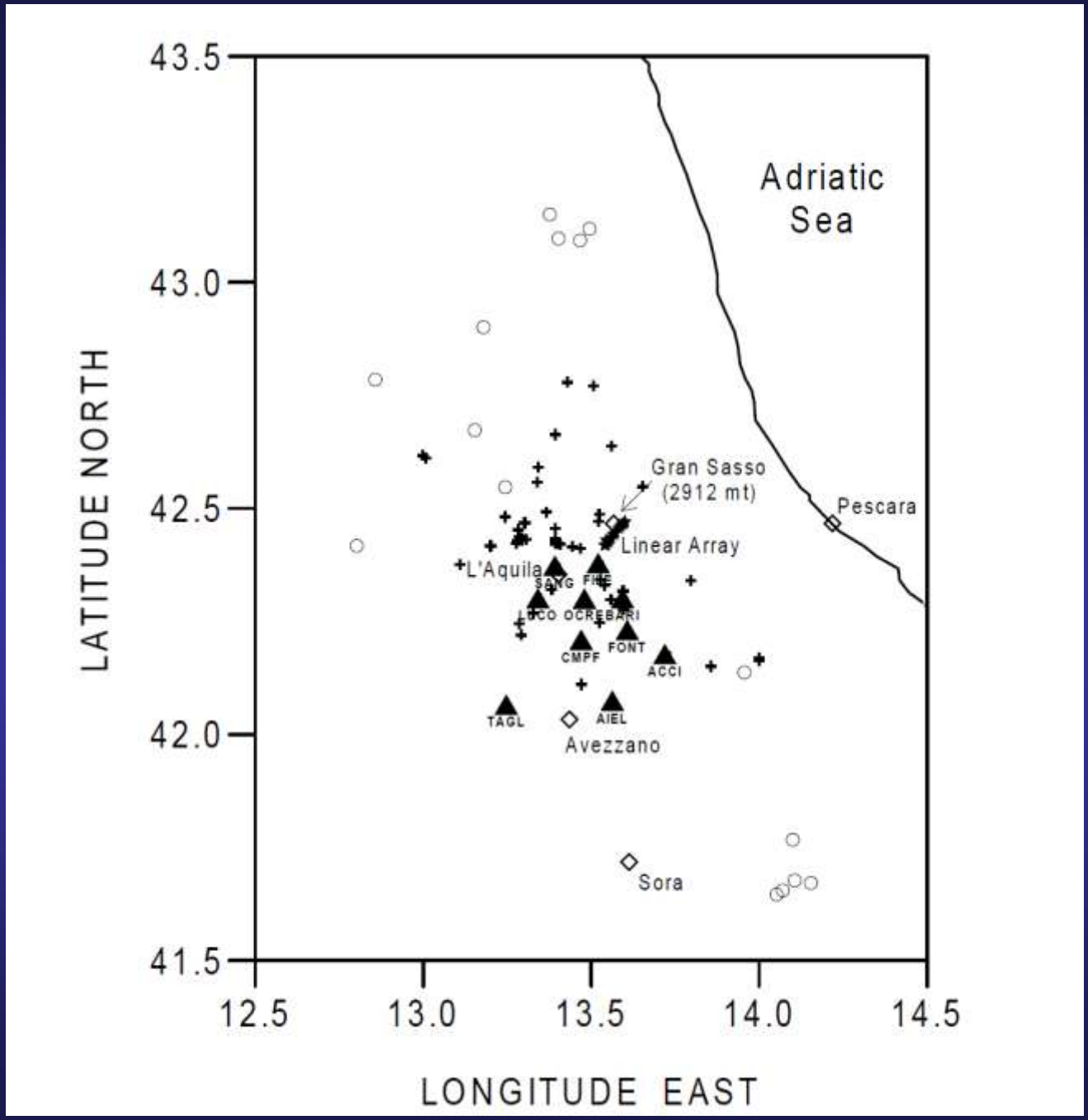
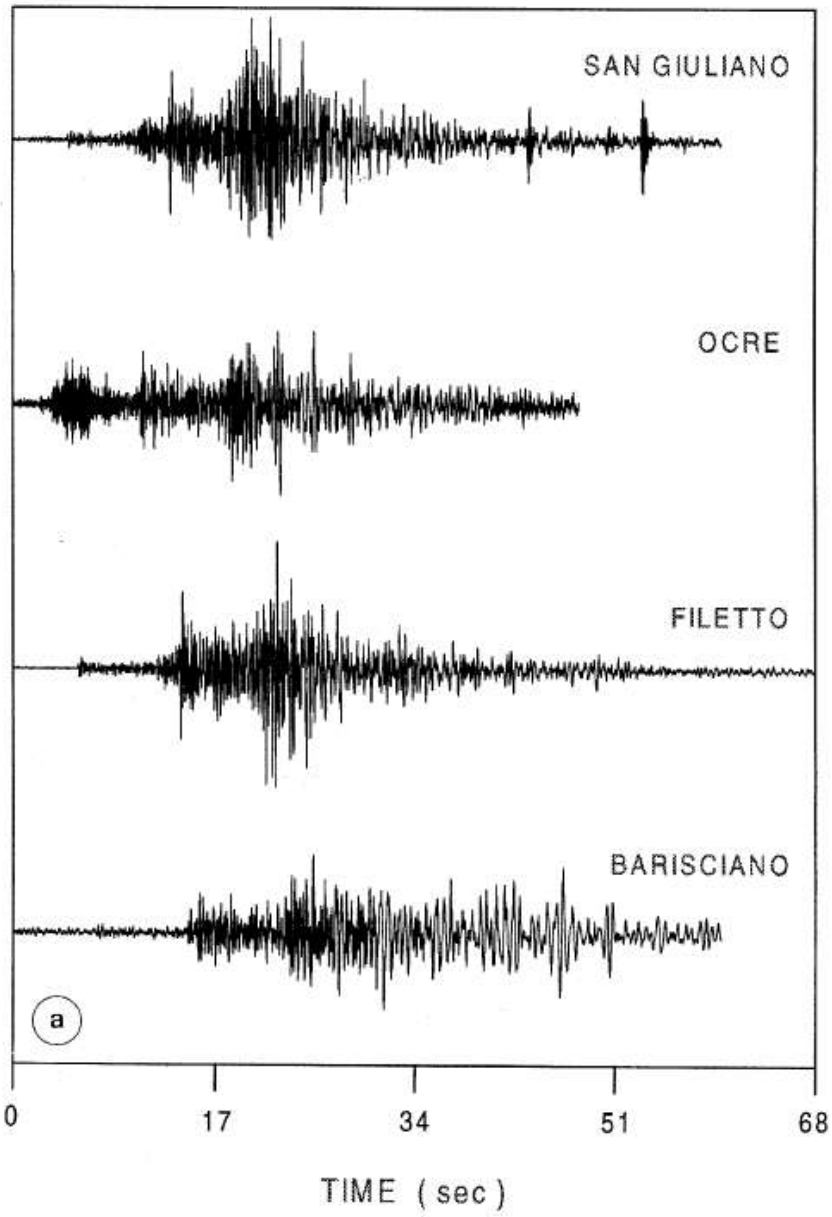


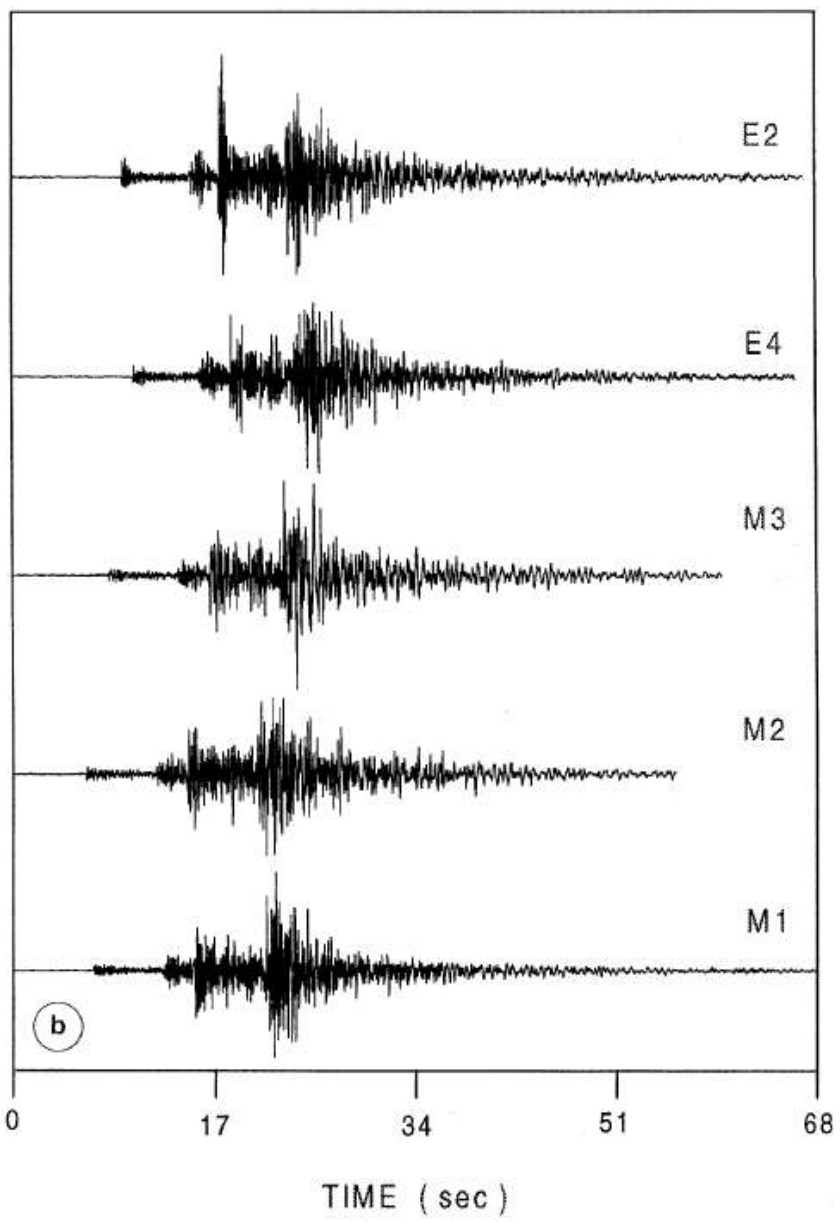
Table 1
Average density of rock cover in different sections of the Gran Sasso tunnel

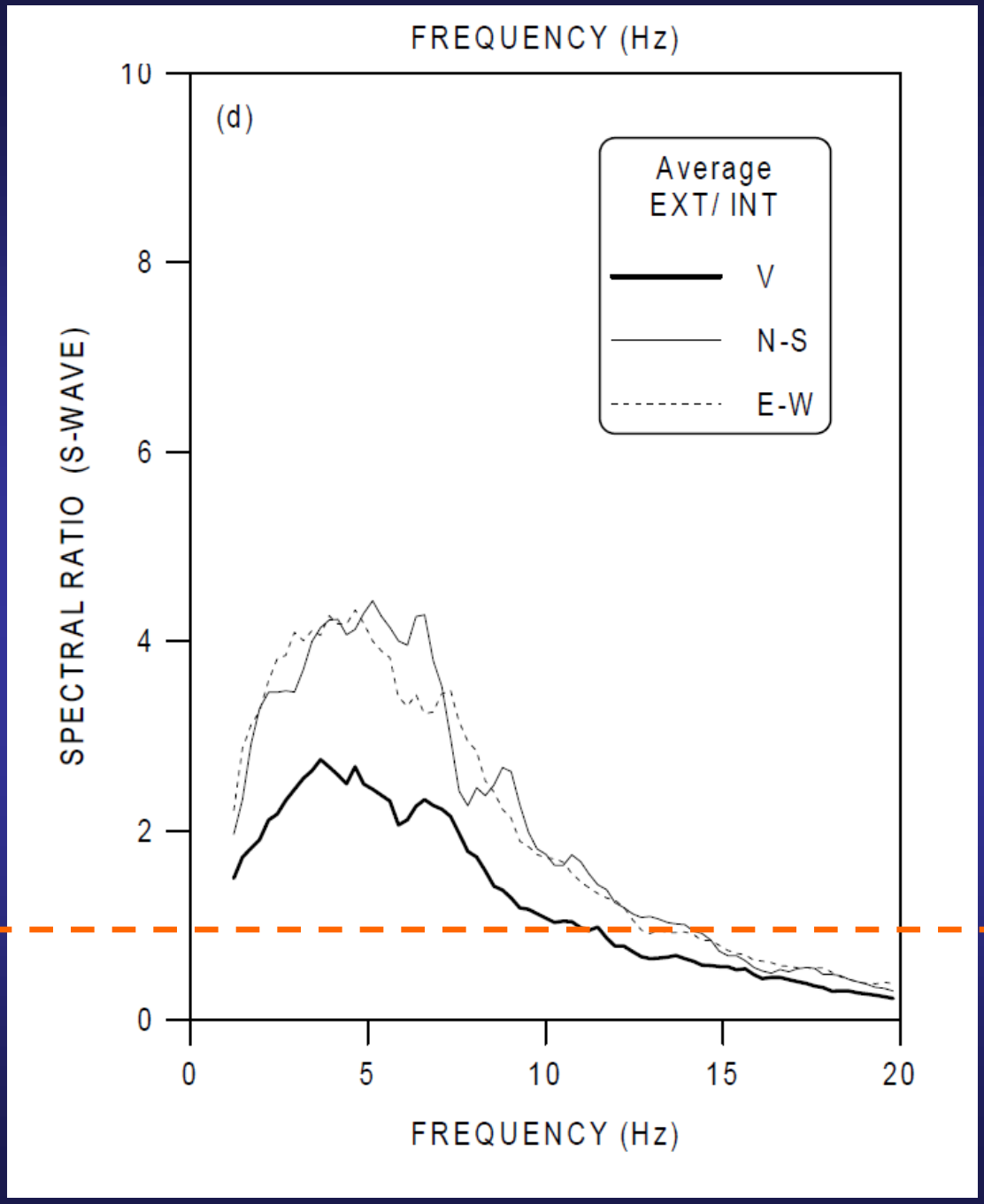
Section no.	Distance from SW entrance (m)	Density (kg m^{-3})
1	500–1500	2710 ± 70
2	1500–2500	2430 ± 60
3	2500–3000	2750 ± 100
4	3000–4000	2710 ± 70
5	4000–4500	2710 ± 100
6	4500–5750	2510 ± 50
7	5750–7500	2720 ± 50
8	7500–10160	2750 ± 100



De Luca G. et al. (1998). Site response study in Abruzzo (Central Italy): underground array versus surface stations. Journal of Seismology 2, 223-236.


18 MAR 1993 - 11:36 VERTICAL
SAN GIULIANO
OCRE
FILETTO
BARISCIANO
a
0
17
34
51
68
TIME (sec)


18 MAR 1993 - 11:36 VERTICAL
E2
E4
M3
M2
M1
b
0
17
34
51
68
TIME (sec)


FREQUENCY (Hz)
(d)
Average
EXT/ INT
V
N-S
E-W
SPECTRAL RATIO (S-WAVE)
10
8
6
4
2
0
0
5
10
15
20
FREQUENCY (Hz)

1

my idea of
Underground Seismic Array (USA)

Nuclear Physics B (Proc. Suppl.) 35 (1994) MAY 1994

TAUP 93

Proceedings of the Third International Workshop on Theoretical and Phenomenological Aspects of Underground Physics

Laboratori Nazionali del Gran Sasso, INFN, Italy
19-23 September 1993

Edited by

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Assergi, Italy

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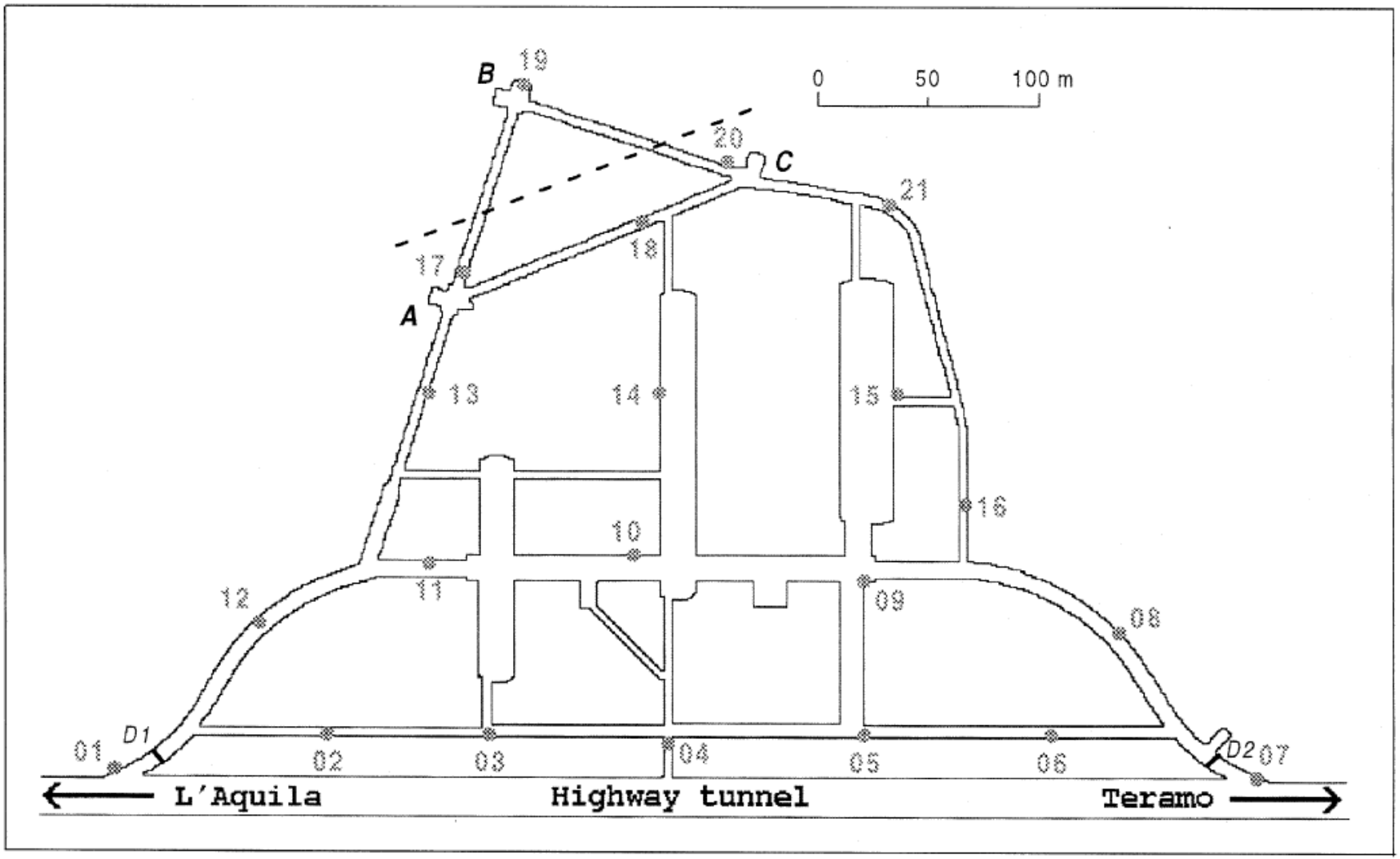
Dipartimento di Fisica, Università di Milano and INFN
Milano, Italy

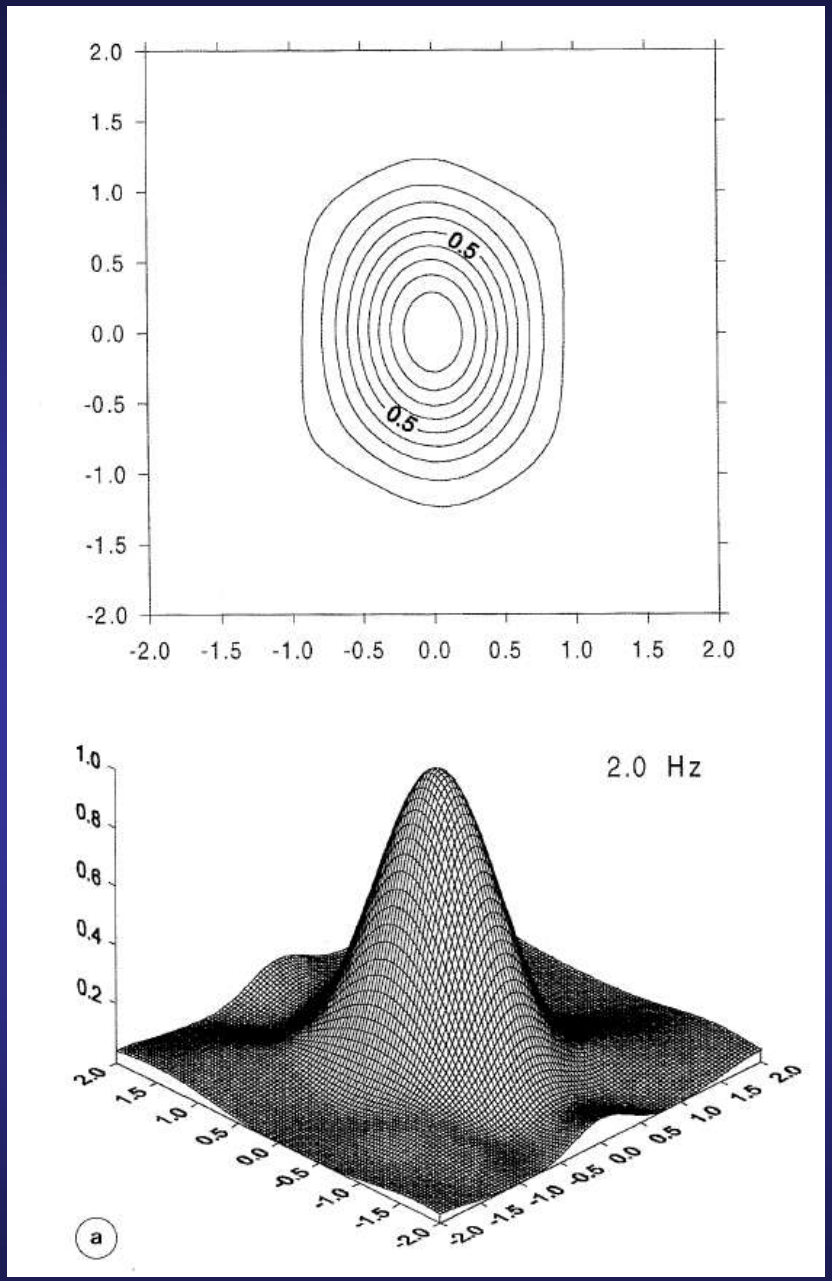
A. BOTTINO
Dipartimento di Fisica Teorica, Università di Torino and INFN
Torino, Italy

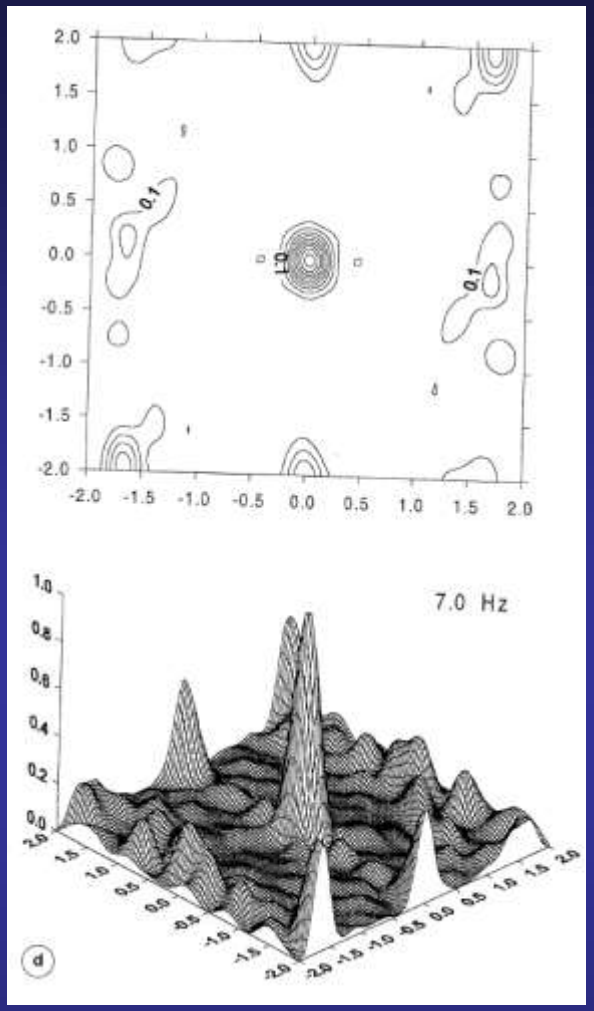
Part 5. Closing session

Review talks
Chairmen: A.E. Chudakov, M. Deutsch

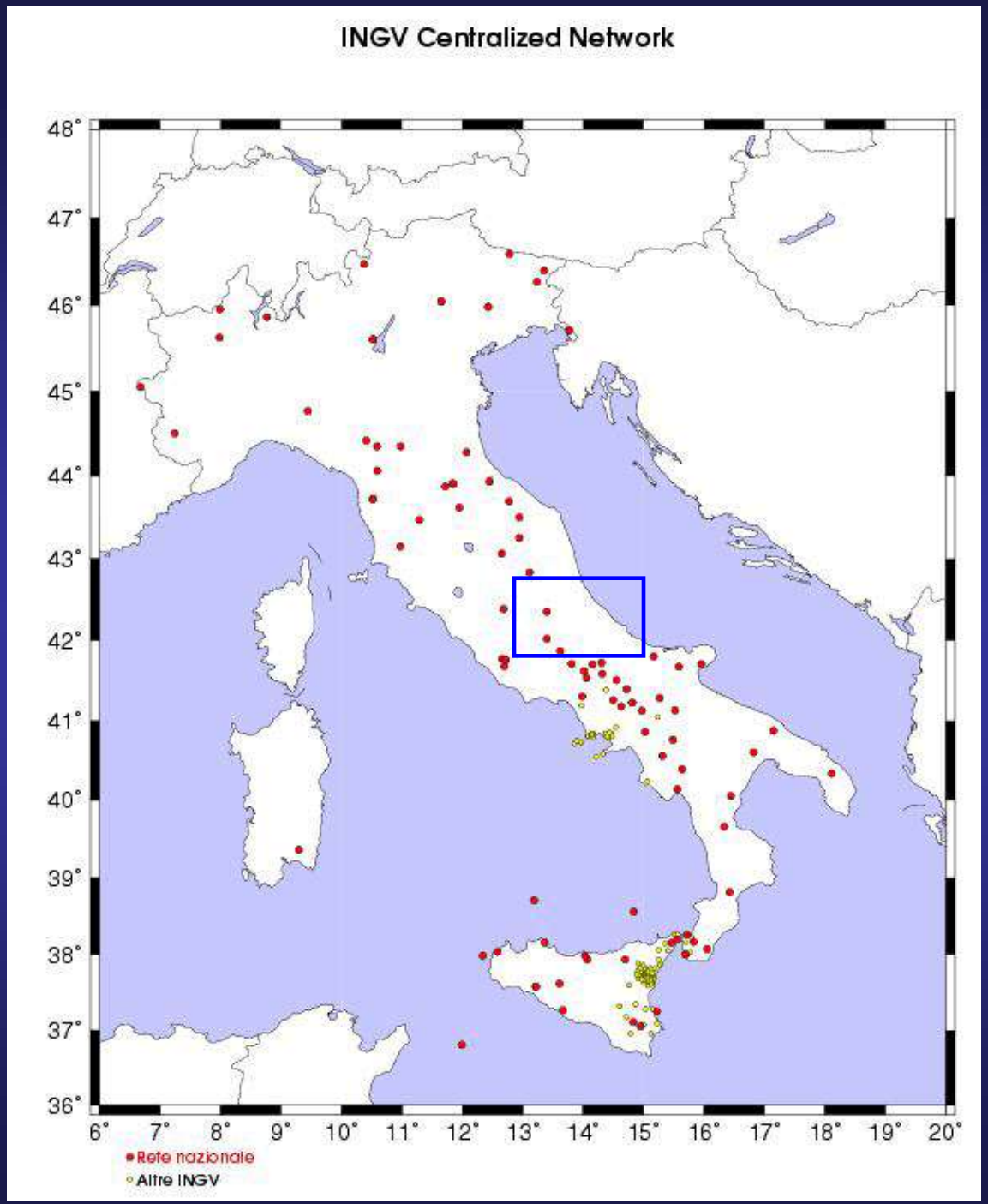


De Luca G. ***et al.*** (1997). Underground earth strain and seismic radiation measurements with a laser interferometer and a dense small-aperture seismic array. Annali di Geofisica XL (5), 995-1005.

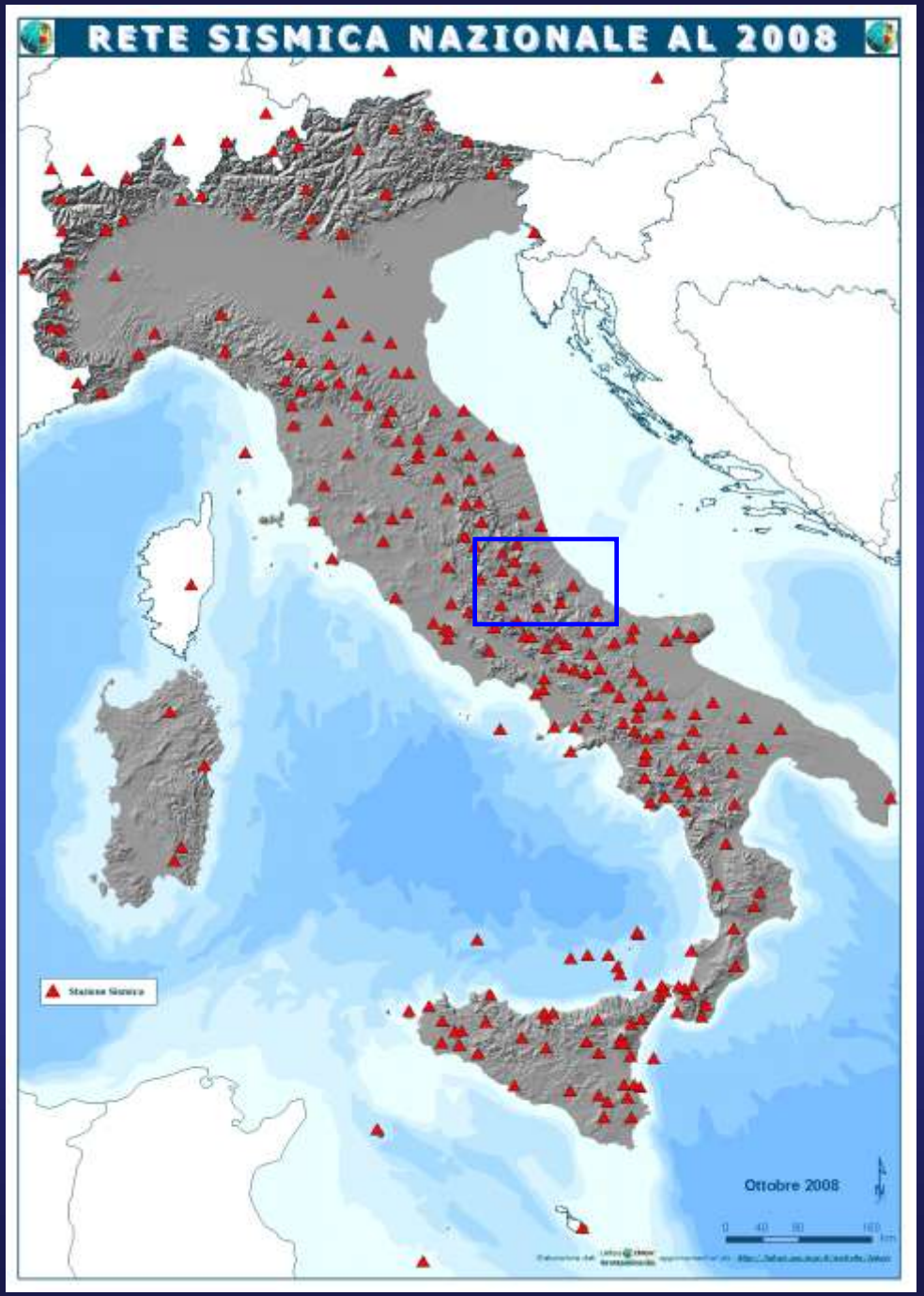




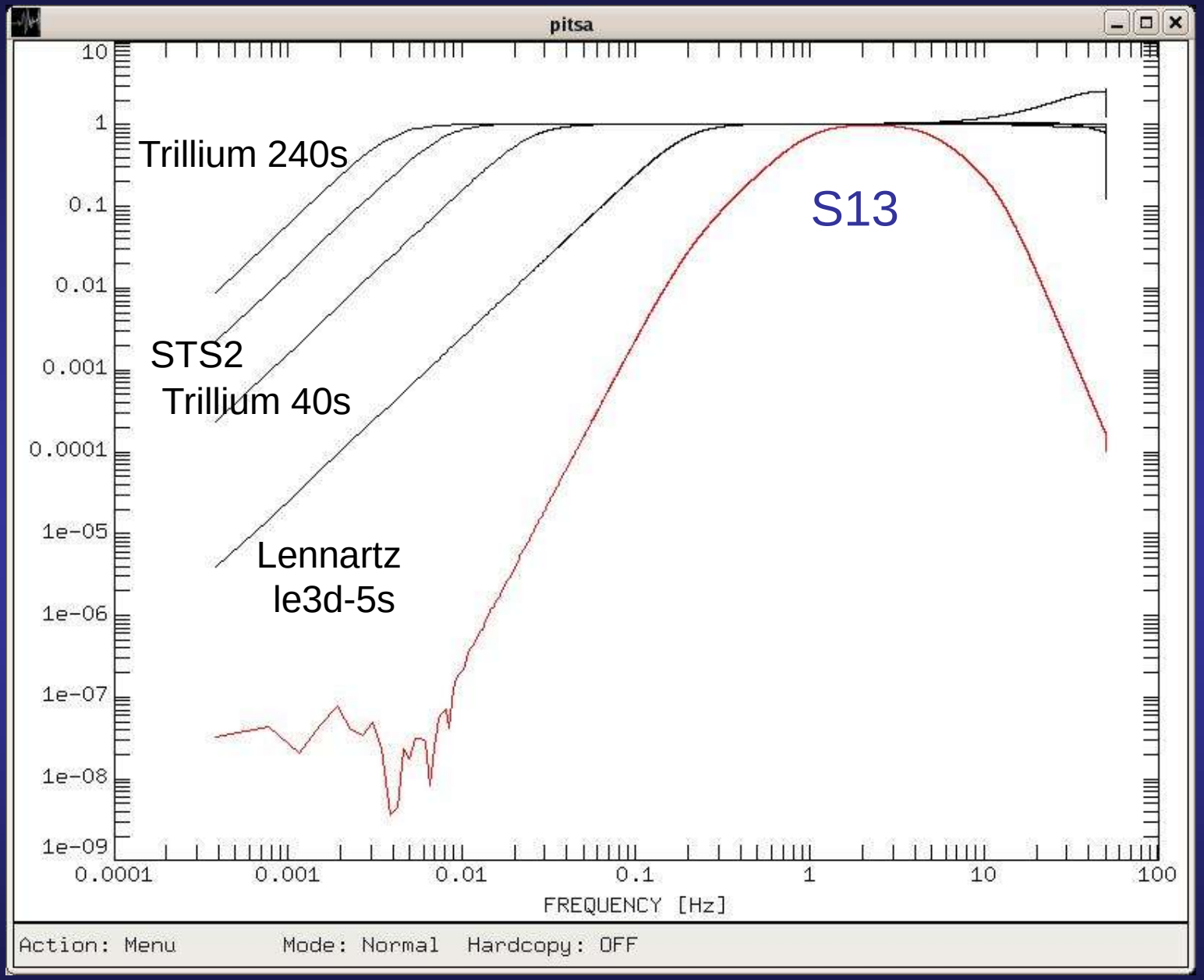
Analysis of slowness (s/km) beam patterns produced by array impulse responses (Capon, 1969) for vertical component of motion



Situation at the end of 2002


RETE SISMICA NAZIONALE AL 2008
Ottobre 2008


25 05 2006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S13
STS2
Trillium 40s
Lennartz
le3d-5s
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0.01
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0.0001
1e-05
1e-06
1e-07
1e-08
1e-09
0.0001
0.001
0.01
0.1
1
10
100
FREQUENCY [Hz]
Action: Menu
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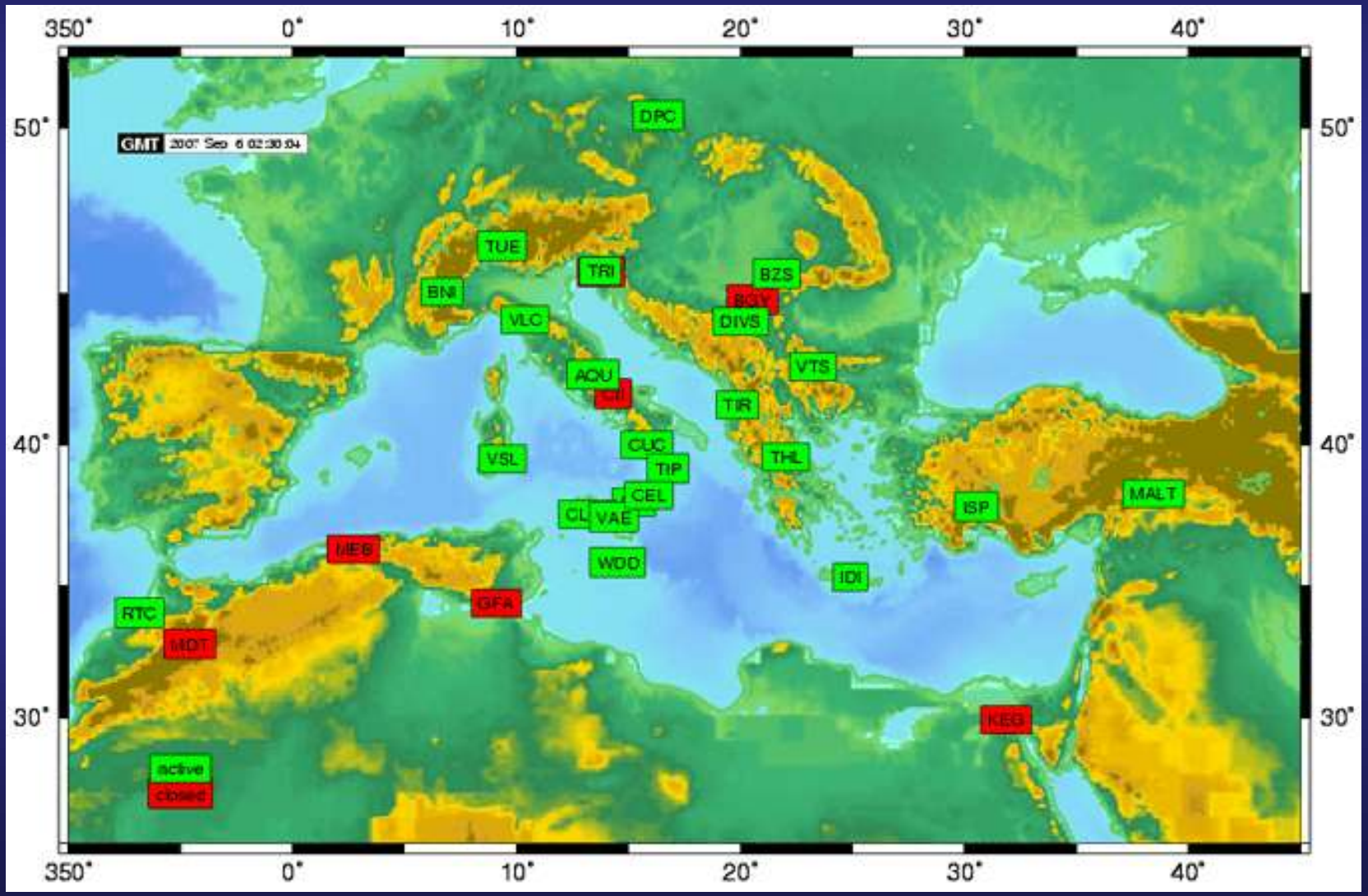
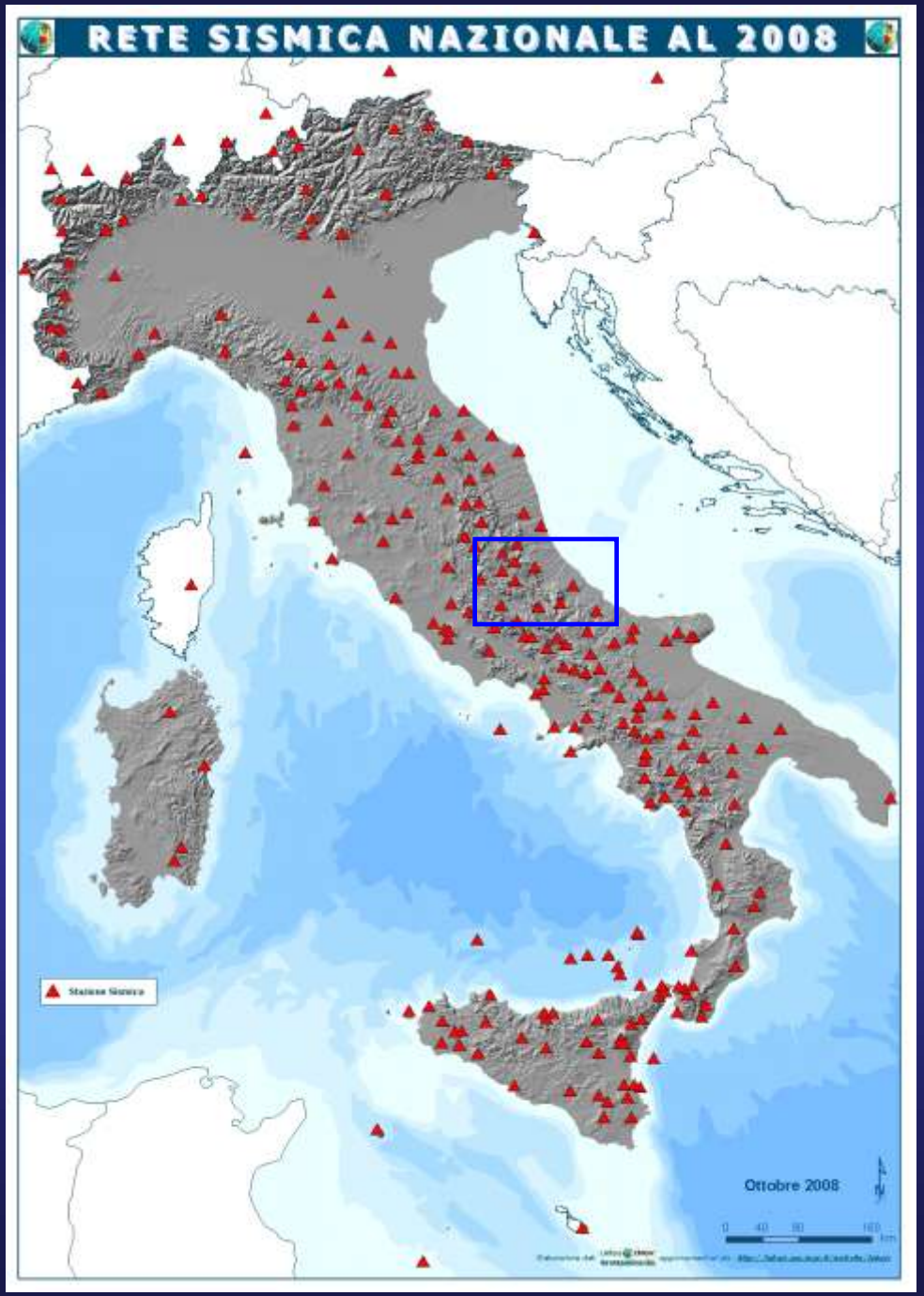
MEDiterranean NETwork

STS1-VBB sensors – 24 bit Quanterra data loggers




RETE SISMICA NAZIONALE AL 2008
Ottobre 2008

… some of history (old)

(of regional seismic network of Abruzzo)

- End of 1991 – (*Seismic Survey Office)* – Start with 7 staz until to 16 (end to 1997)
- Definitively dismantled at the end of 2002 and the begin of 2003 (political problem !!!)
- Transfer to the INGV nel 2004

Instrumentation

- 40 Mars88-FD (Floppy disk) – Lennartz
- 3 Mars88-MO (Magneoptical disk 5 ¼ - 330 MB)
- Time: DCF + GPS
- 35 Mark L4C-3D (1 Hz)
- 6 Terne Mark L4C (1 Hz)

2005

(my office c/o *LNGS*)

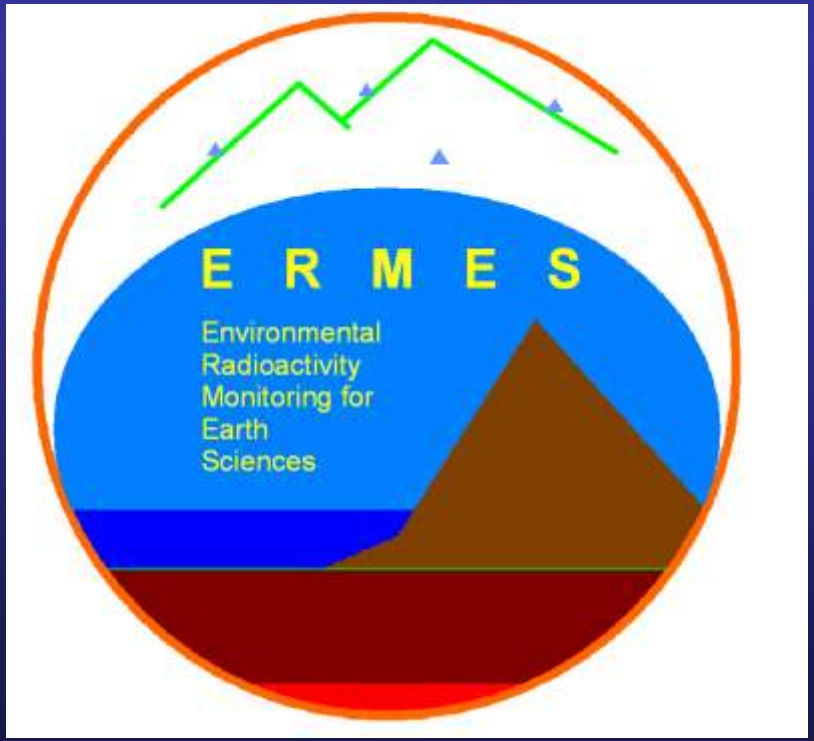
… some of history (now)

(of regional seismic network of Abruzzo)

2007: ERMES

December 2005: first two stations

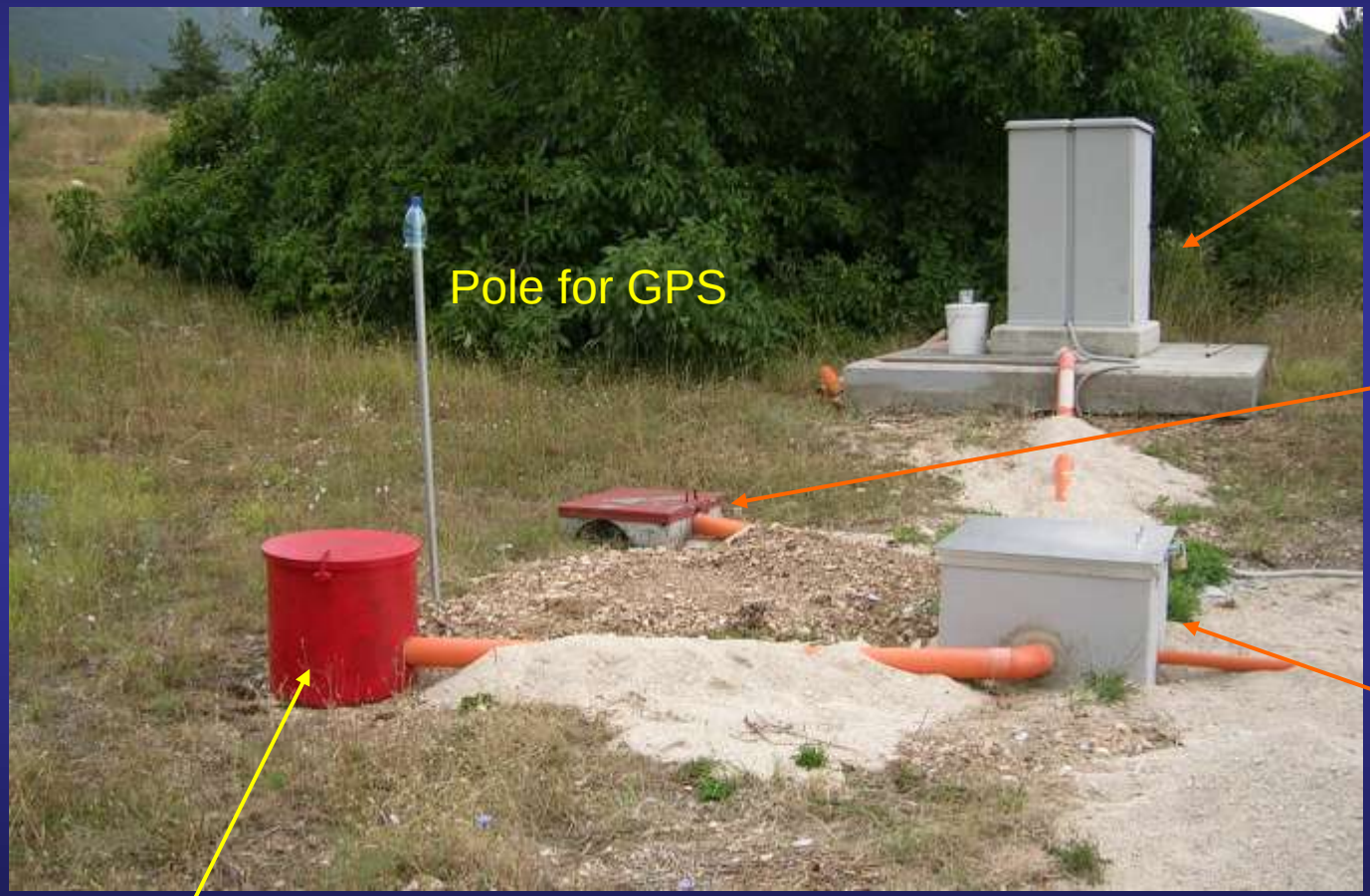
April 2007: last two stations



External building of *LNGS* (INFN)

Site preparation

(Staz. GSO2 c/o *LNGS*)



Site preparation

(Staz. SEM1 c/o *Ortobotanico di Sant'Eufemia a Maiella*)

Restoration of site of old network

(Staz. BRS1 c/o *Vivaio Forestale of Barisciano - AQ*)

Restoration of site of old network

(Staz. BRS1 c/o *Vivaio Forestale of Barisciano - AQ*)

GPS Receiver

Modem GSM

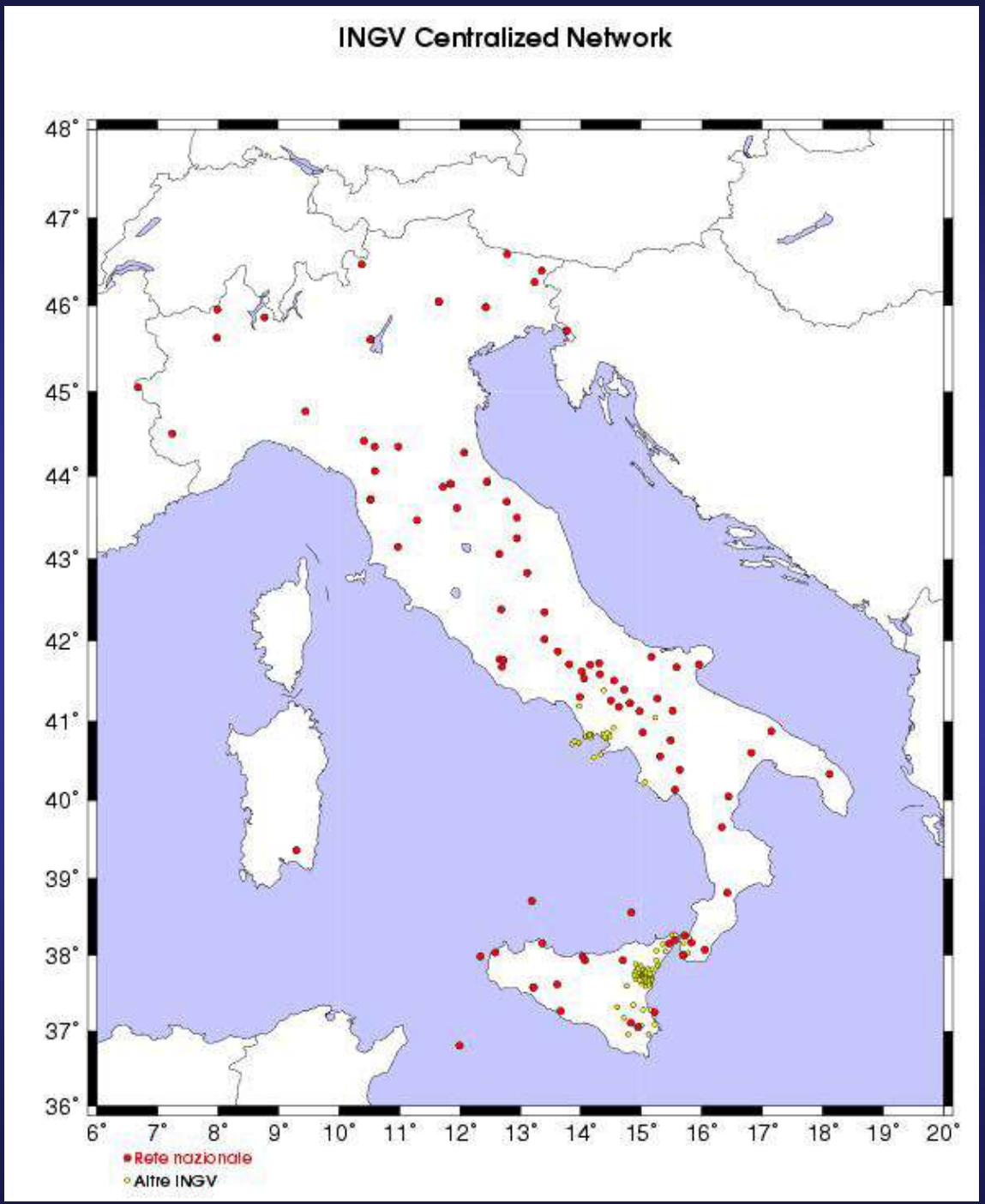
Mars88 - MC

Restoration of site of old network

(Staz. BRS1 c/o *Vivaio Forestale of Barisciano - AQ*)

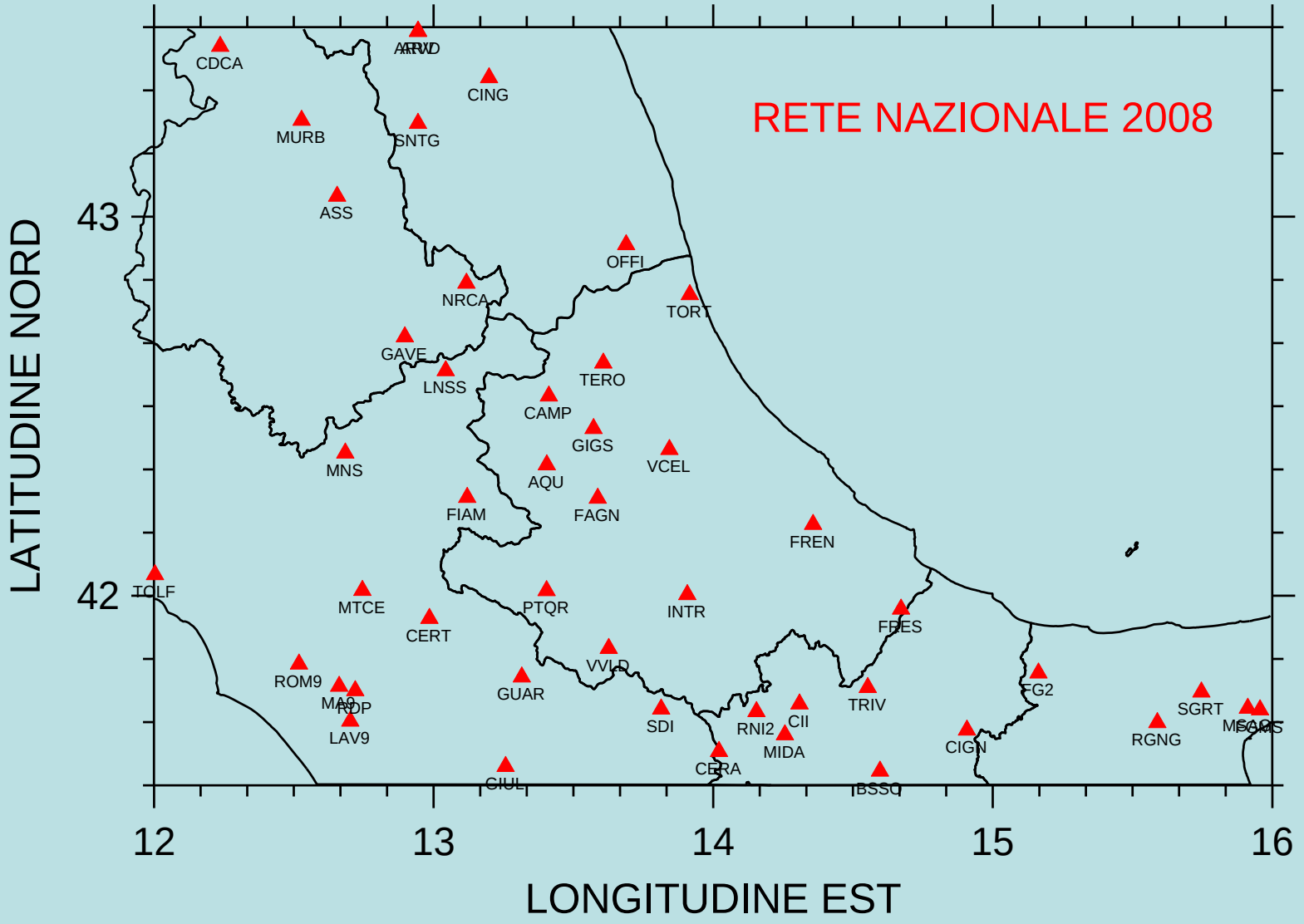
Restoration of site of old network

(Staz. CMF1 c/o Campo Felice - *elevation: 1675 m*)

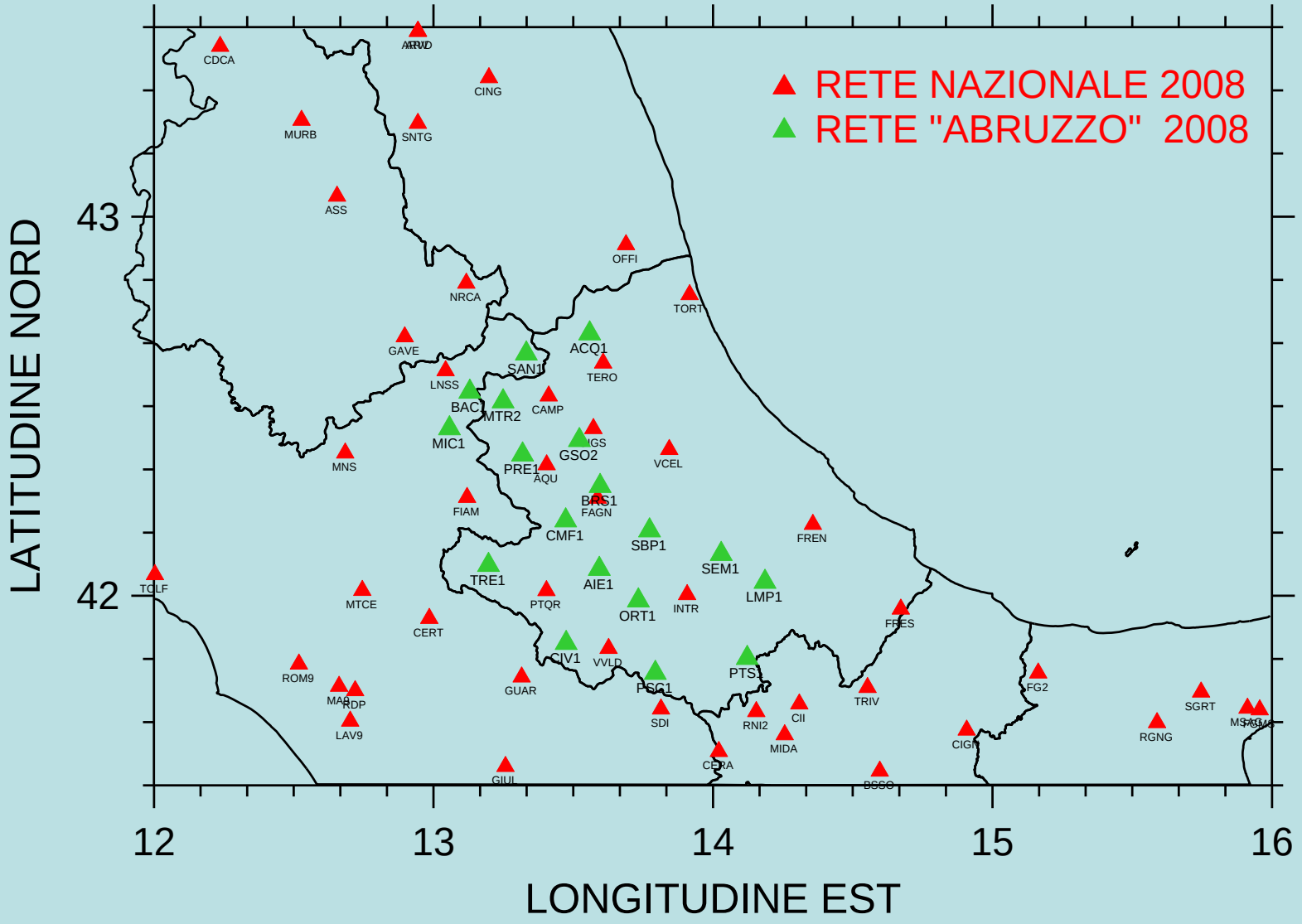


Situation at the end of 2002

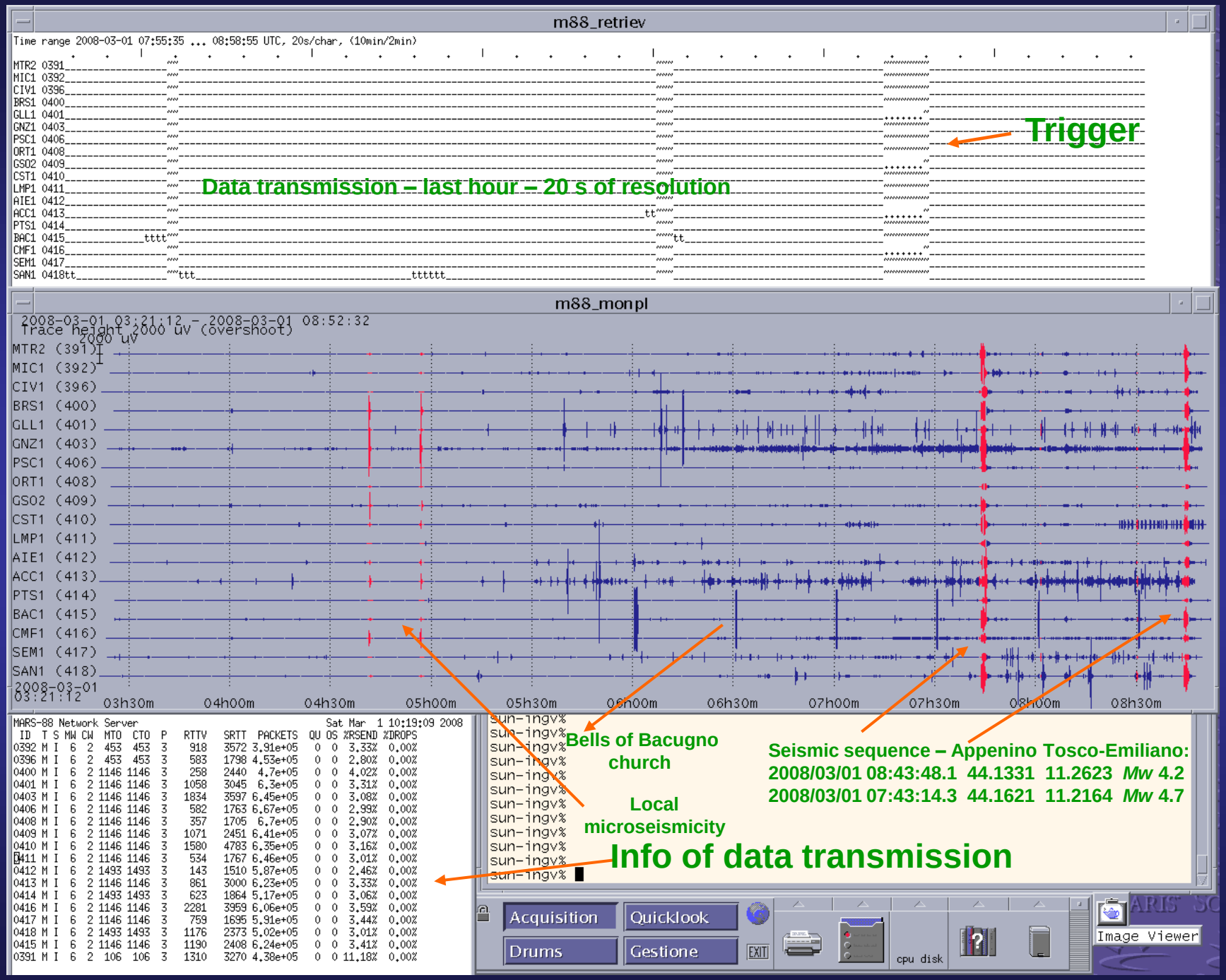
National Seismic Network (2008)



January 2009



2007 - (my office c/o *LNGS*)



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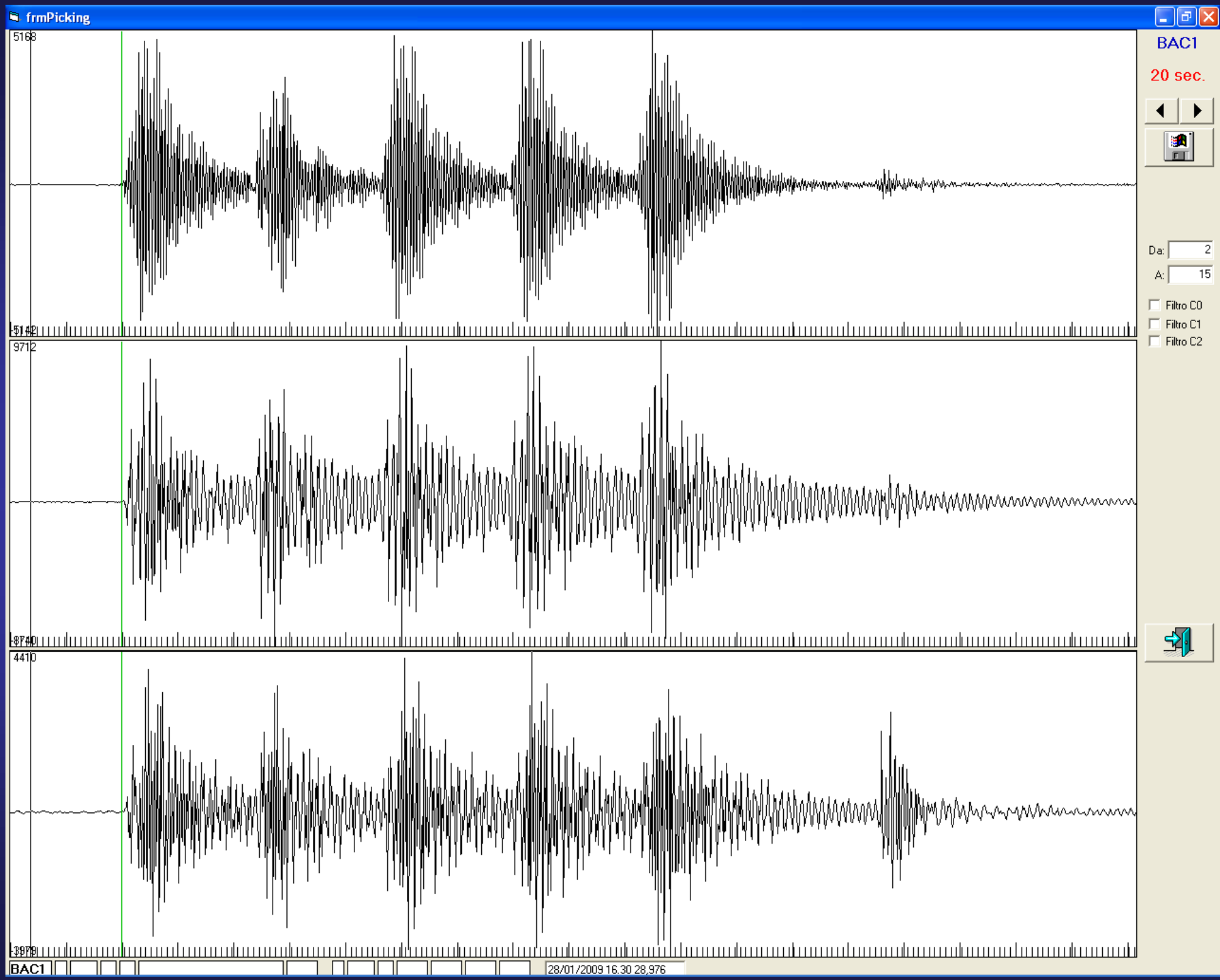
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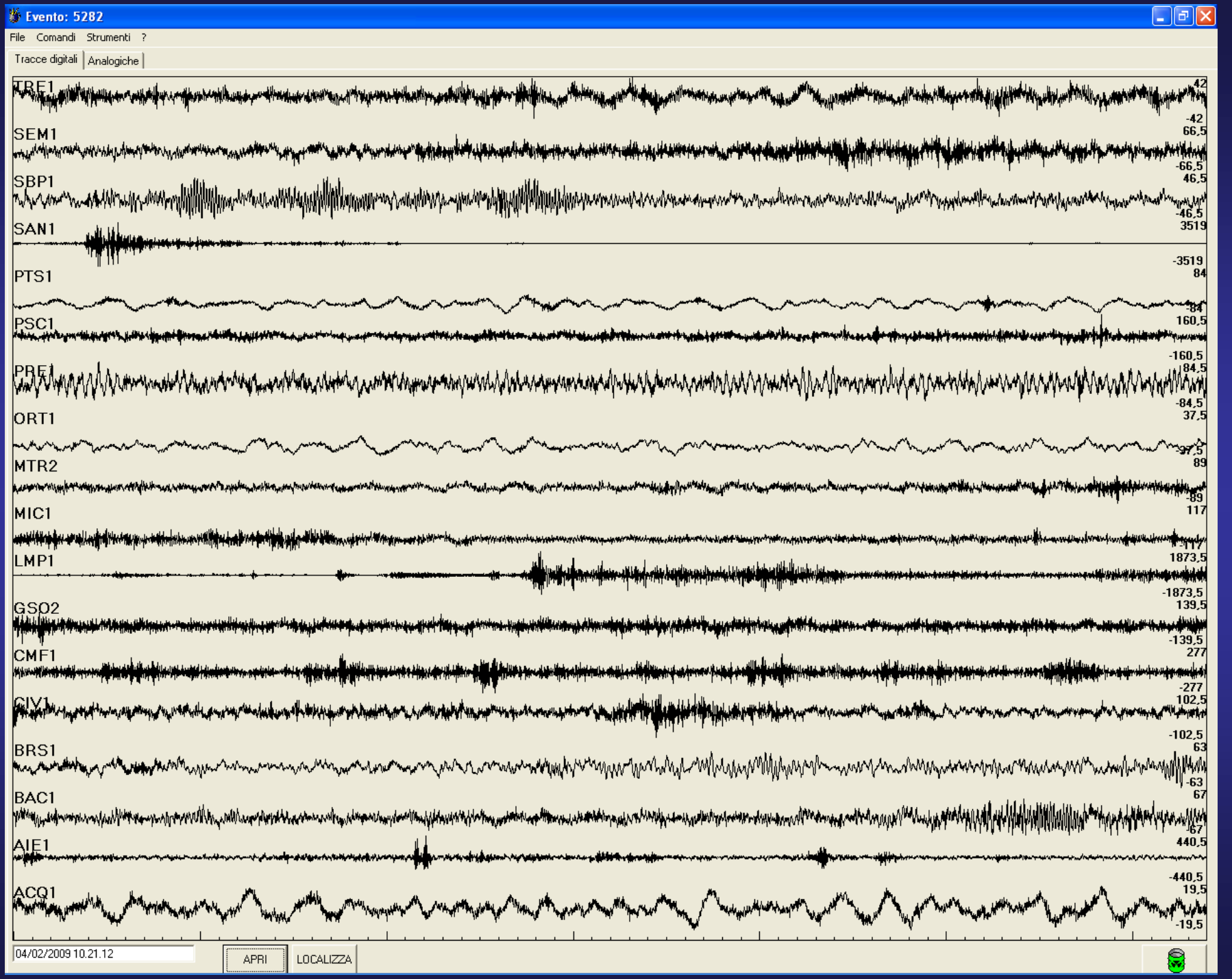
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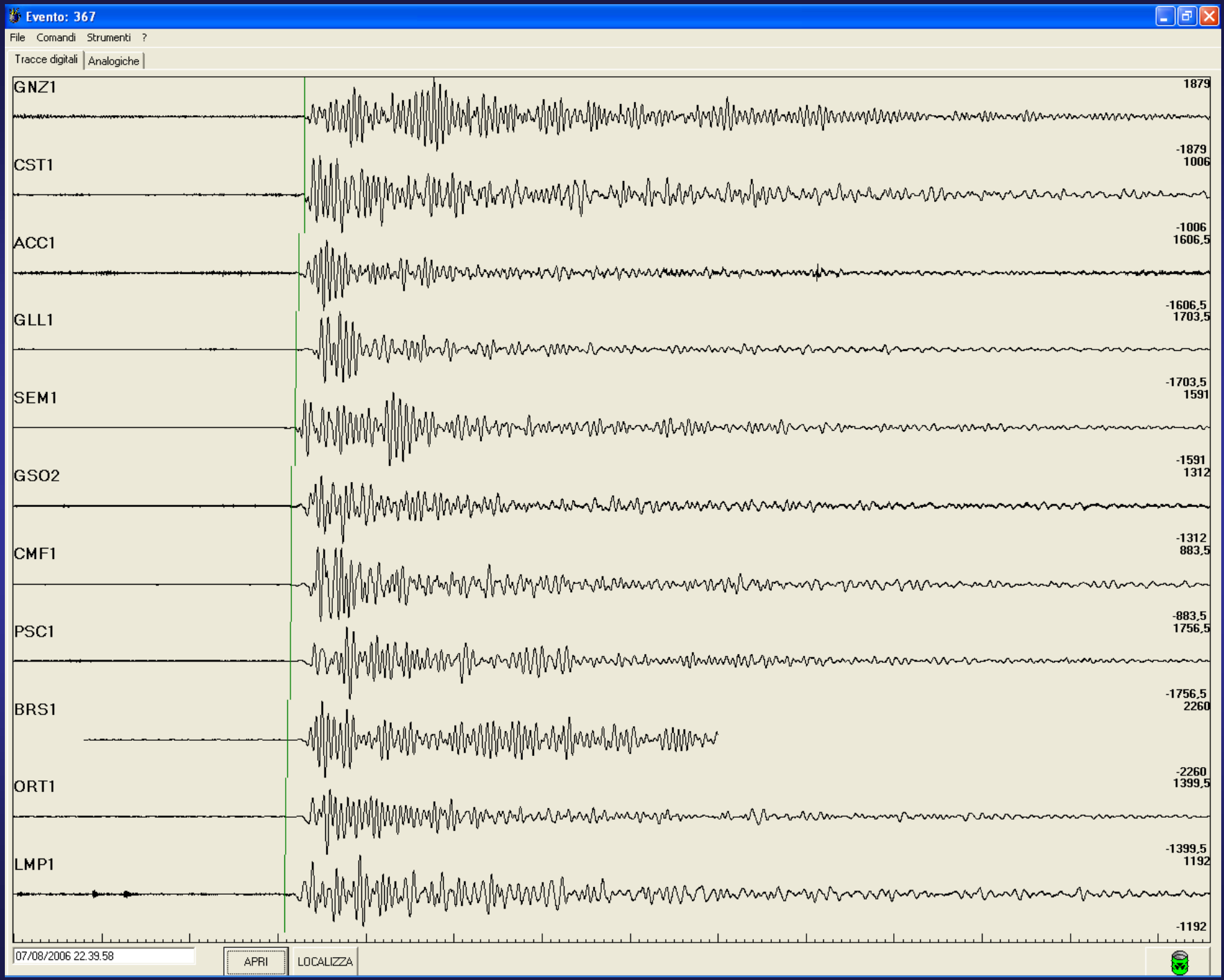
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GSO2
-1591
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2260
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LOCALIZZA

Centre Sismologique Euro-Méditerranéen
European-Mediterranean Seismological Centre

Google™ Custom Search | Search EMSC

Current time: 2009-02-07 15:00:40 UTC

Earthquake information | Euro-Med seismicity | How it works | Database & Documents | News | Pro

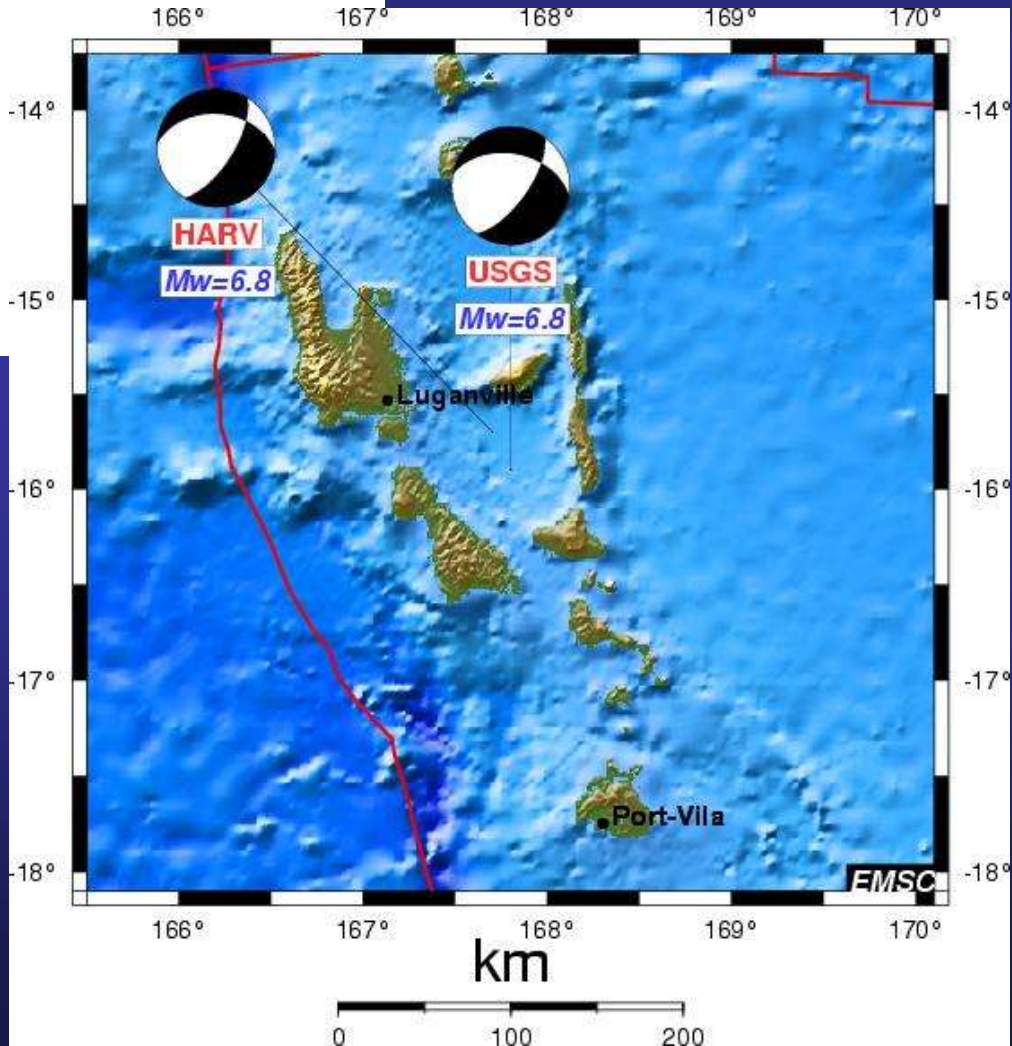
Earthquake Information

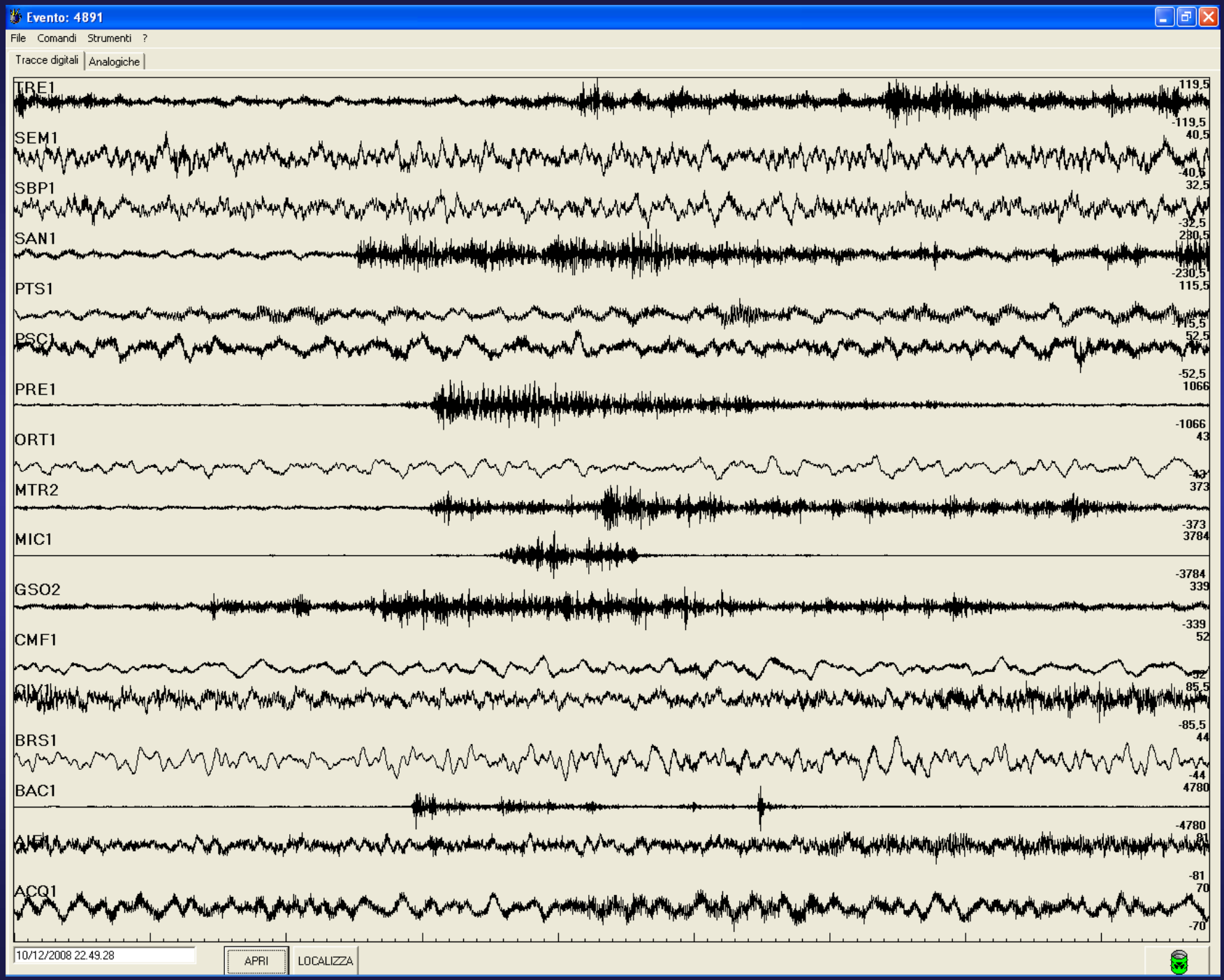
Summary | Maps | Regional seismicity | More Information

Summary:

- Magnitude **Mw 6.8**
- Region **VANUATU**
- Date time **2006-08-07 at 22:18:53.5 UTC**
- Location **15.77 S ; 167.65 E**
- Depth **140 km**
- Distances 1176 km W Suva (pop 199,455 ; local time 10:18)
  61 km SE Luganville (pop 13,397 ; local time 09:18)
  43 km NE Norsup (pop 2,998 ; local time 09:18)

More seismicity information (Moment tensors, phases pickings, etc.)

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PSC1
52,5
-52,5
PRE1
1066
-1066
ORT1
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-43
MTR2
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-373
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3784
-3784
GSO2
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-339
CMF1
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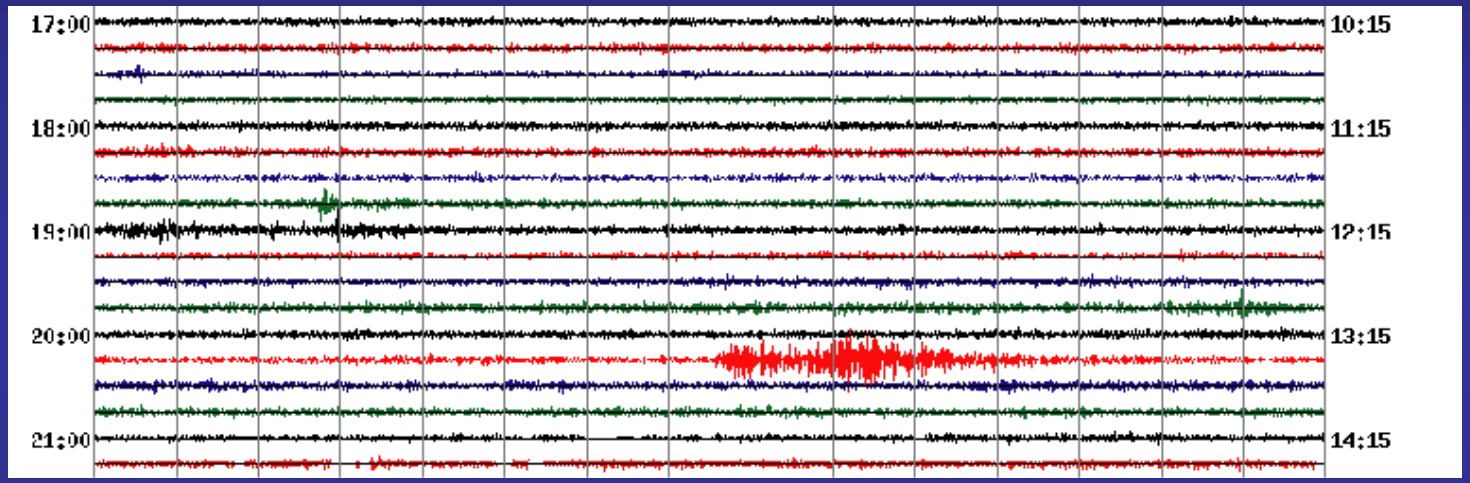
LOCALIZZA

Nonvolcanic Tremor along the San Andreas Fault

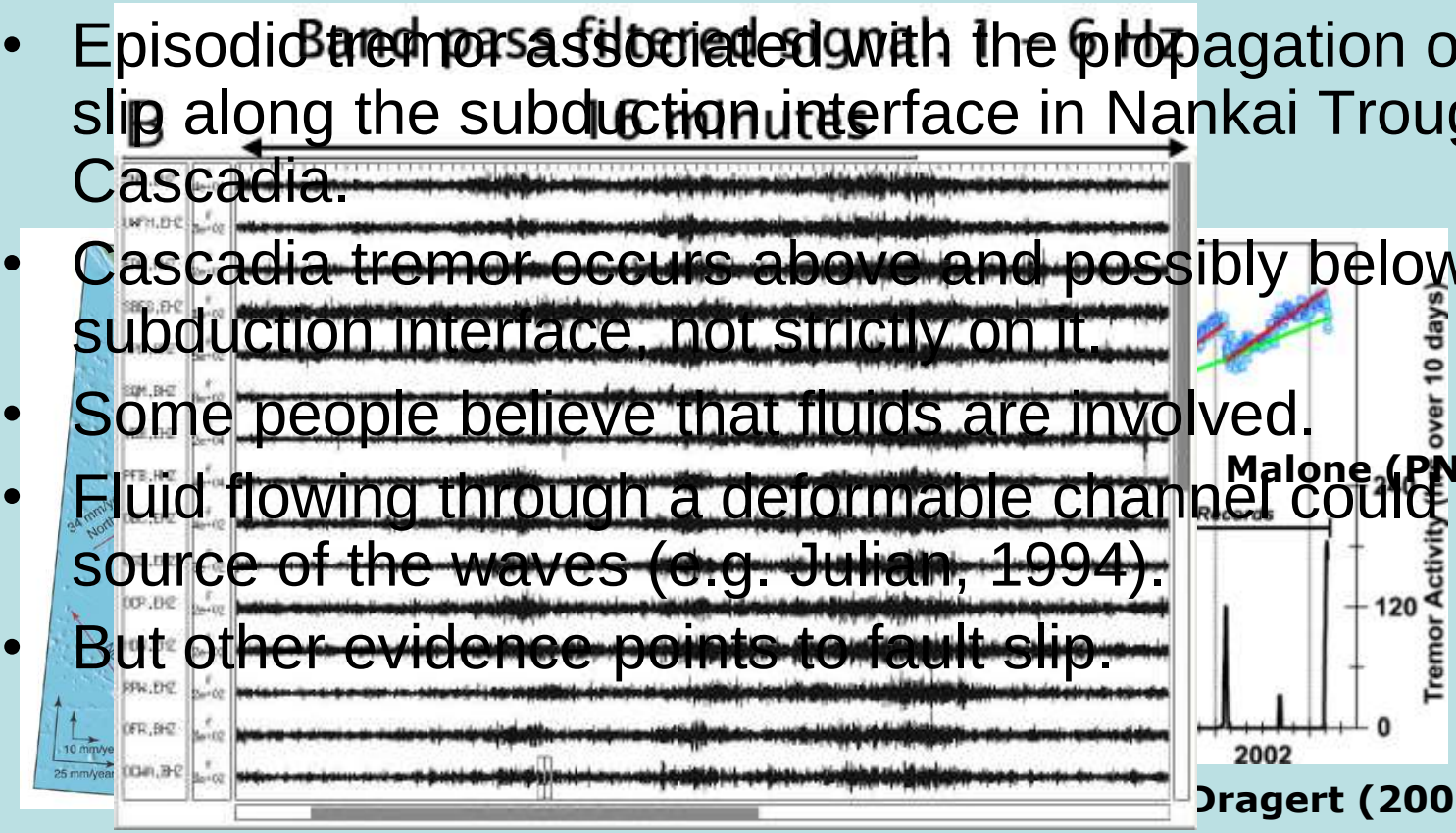


Bill Ellsworth (USGS – Menlo Park)

May 20, 2008

Characteristics of Nonvolcanic Tremor

- Tremor generally occurs below the brittle seismogenic crust.
- Very difficult to correlate phases across seismic networks.
- Episodic tremor associated with the propagation of slow slip along the subduction interface in Nankai Trough and Cascadia.
- Cascadia tremor occurs above and possibly below the subduction interface, not strictly on it.
- Some people believe that fluids are involved.
- Fluid flowing through a deformable channel could be the source of the waves (e.g. Julian, 1994).
- But other evidence points to fault slip.



ARTICLE IN PRESS

TECTO-124434; No of Pages 15

Tectonophysics xxx (2009) xxx–xxx

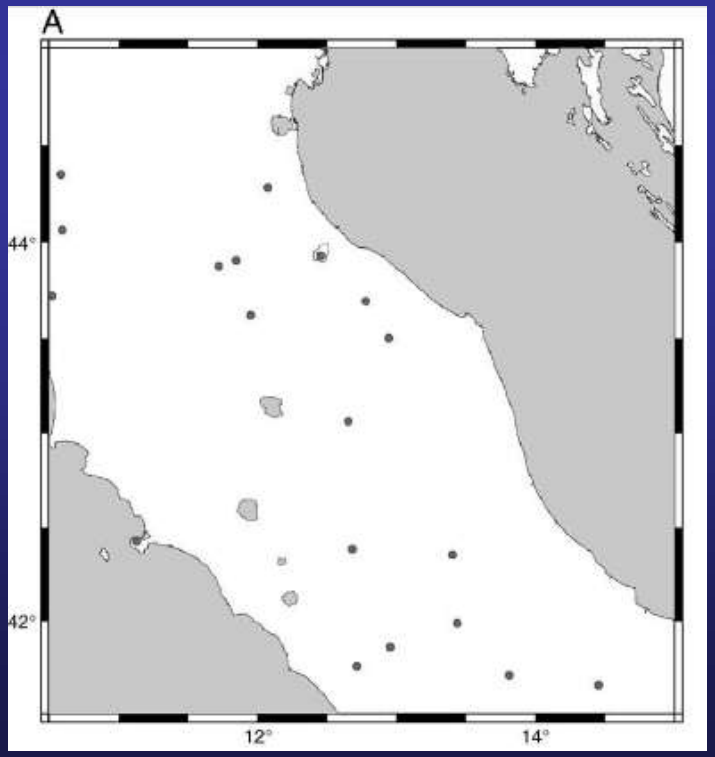
Contents lists available at ScienceDirect

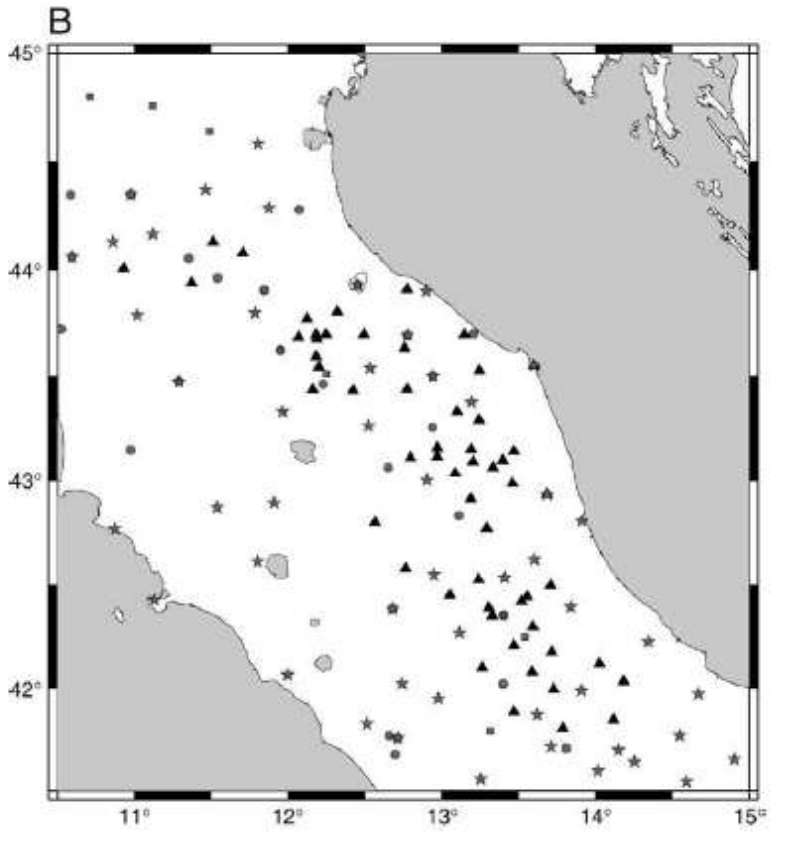
Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

De Luca et al.

Seismicity in Central and Northern Apennines integrating the Italian national and regional networks





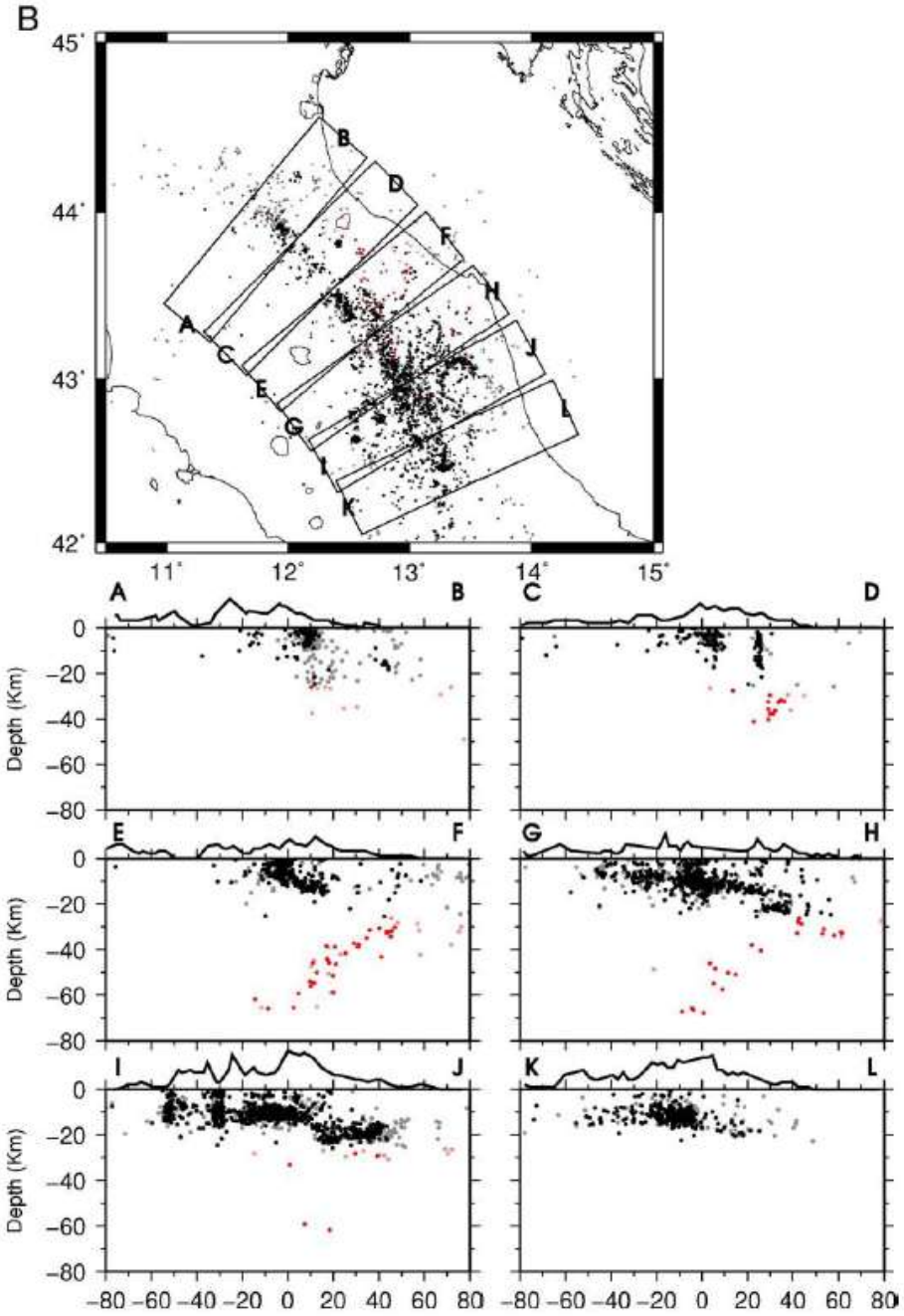
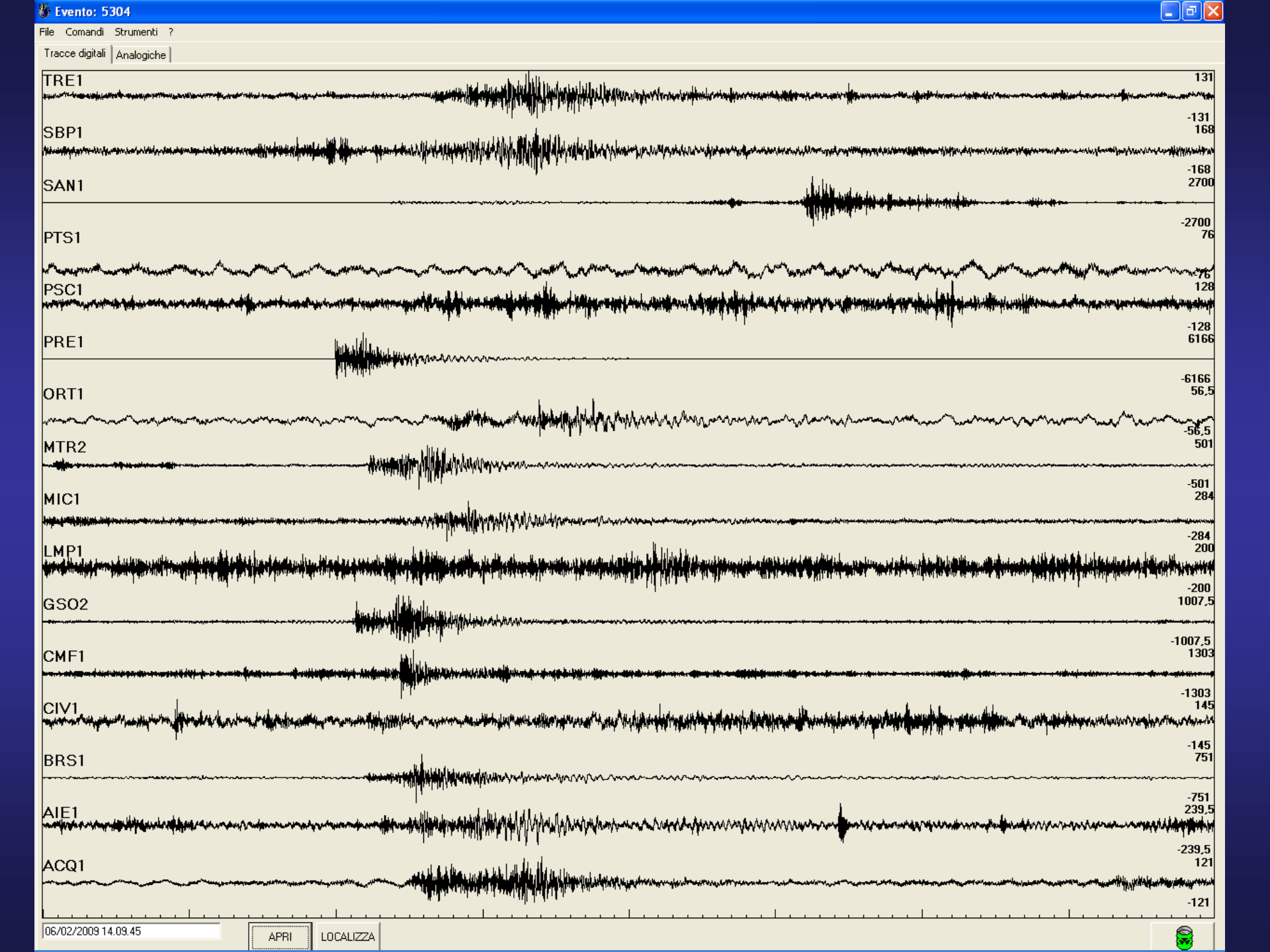


Fig. 8 (*continued*).


Evento: 5304
File
Comandi
Strumenti
?
Tracce digitali
Analogiche
TRE1
131
-131
SBP1
168
-168
SAN1
2700
-2700
PTS1
76
-76
PSC1
128
-128
PRE1
6166
-6166
ORT1
56,5
-56,5
MTR2
501
-501
MIC1
284
-284
LMP1
200
-200
GSO2
1007,5
-1007,5
CMF1
1303
-1303
CIV1
145
-145
BRS1
751
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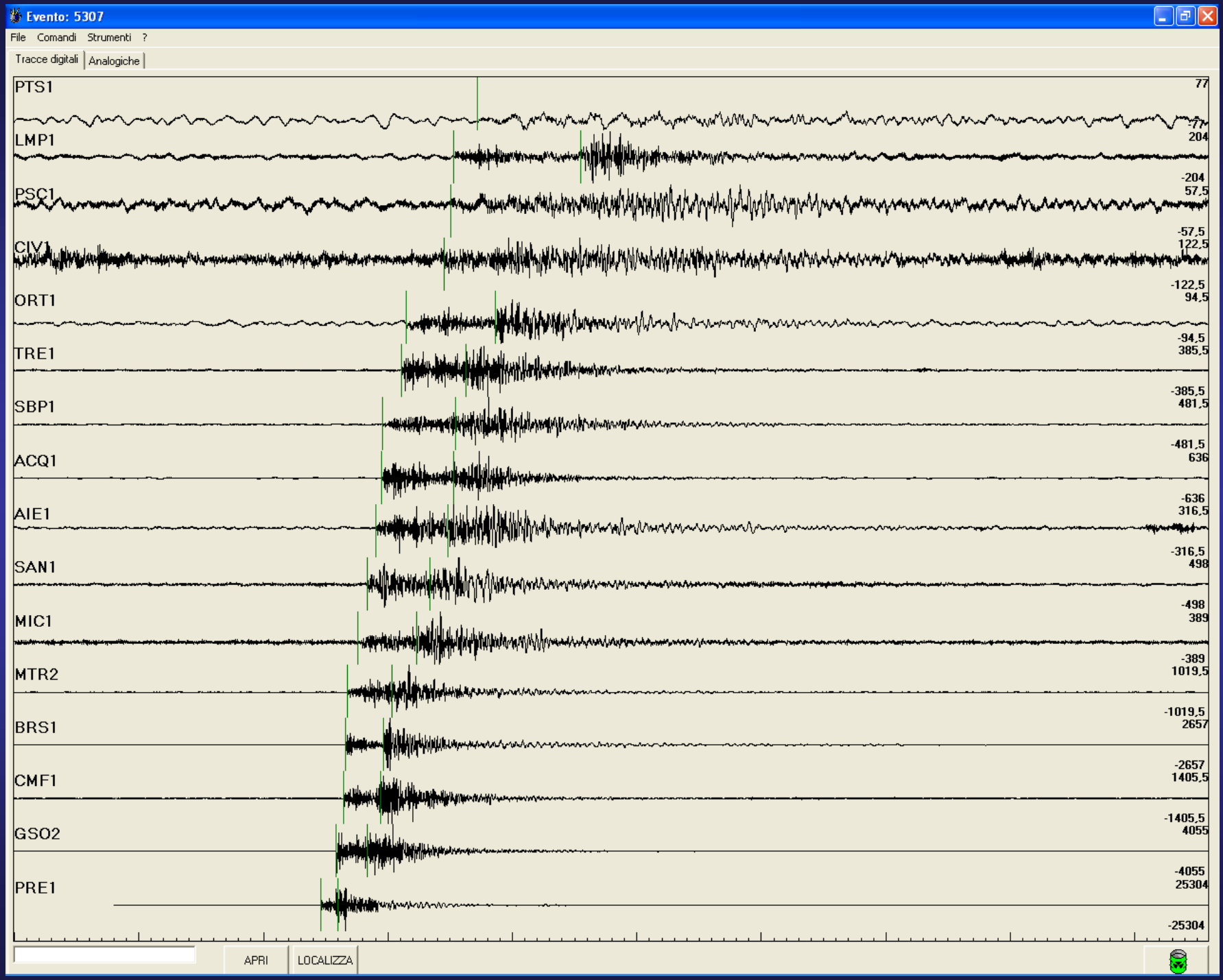
AIE1
239,5
-239,5
ACQ1
121
-121
06/02/2009 14.09.45
APRI
LOCALIZZA


Evento: 5307
File
Comandi
Strumenti
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Tracce digitali
Analogiche
PTS1
77
-77
LMP1
204
-204
PSC1
57,5
-57,5
CIV1
122,5
-122,5
ORT1
94,5
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TRE1
385,5
-385,5
SBP1
481,5
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ACQ1
636
-636
AIE1
316,5
-316,5
SAN1
498
-498
MIC1
389
-389
MTR2
1019,5
-1019,5
BRS1
2657
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CMF1
1405,5
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GSO2
4055
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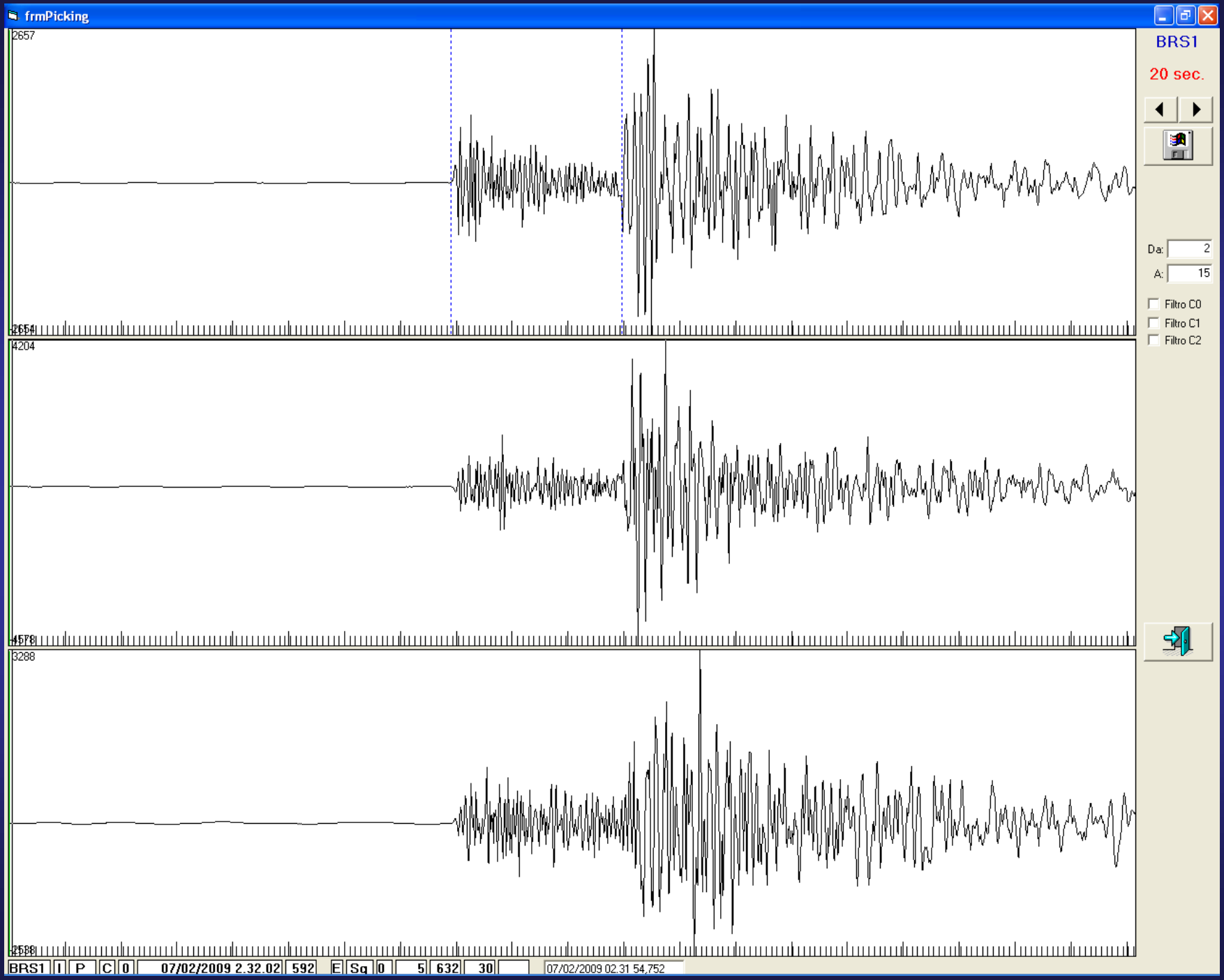
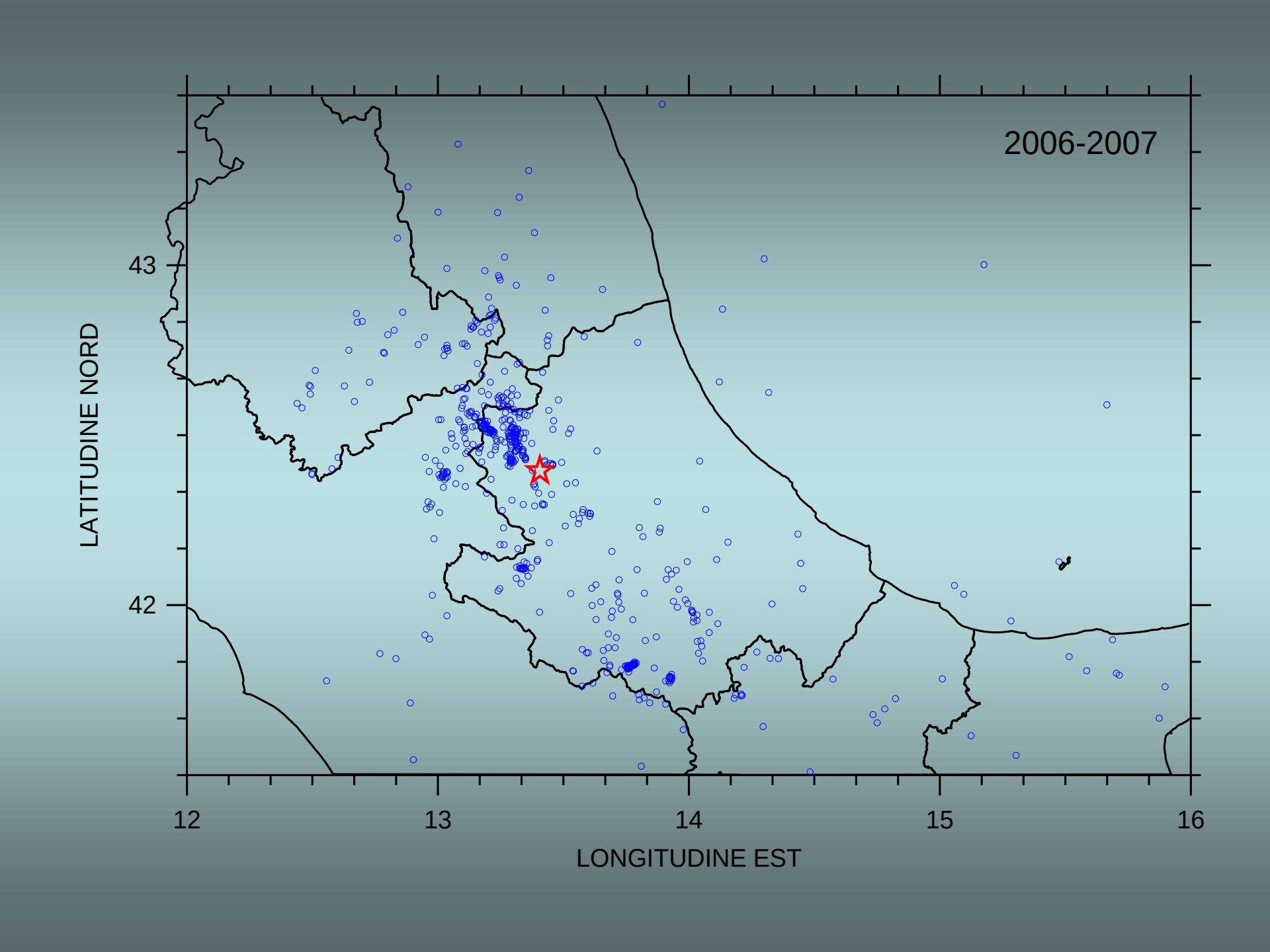
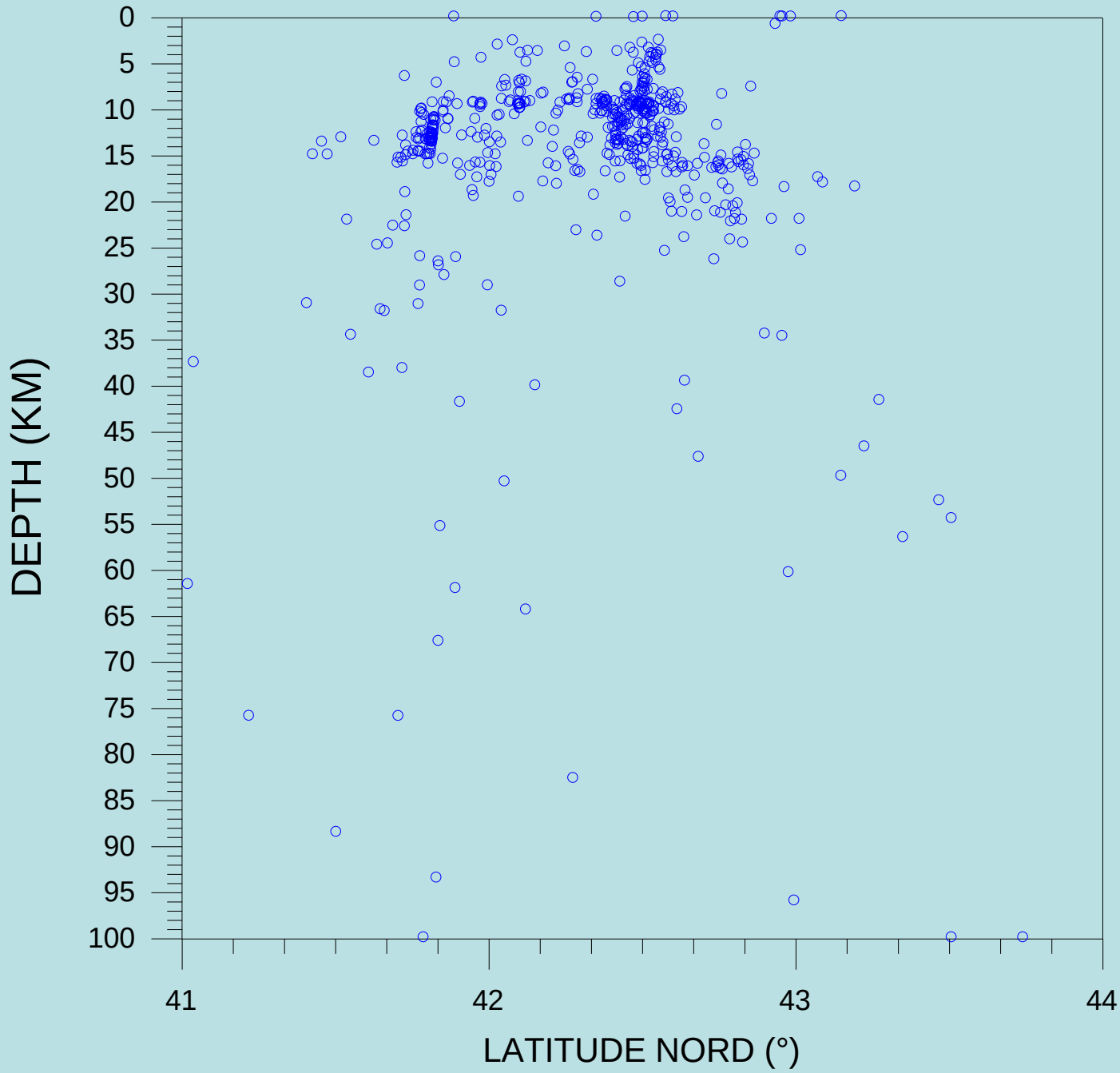
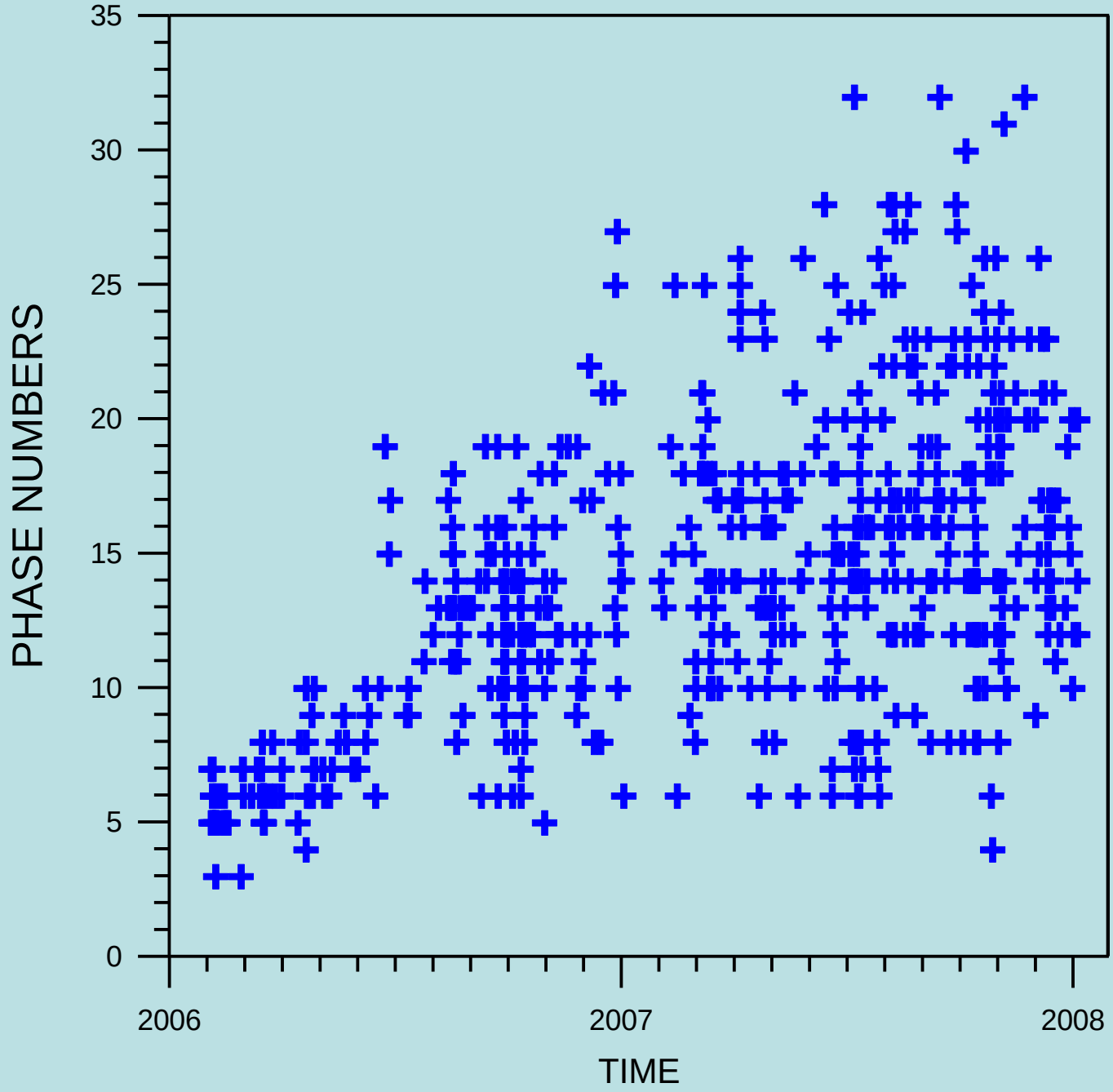
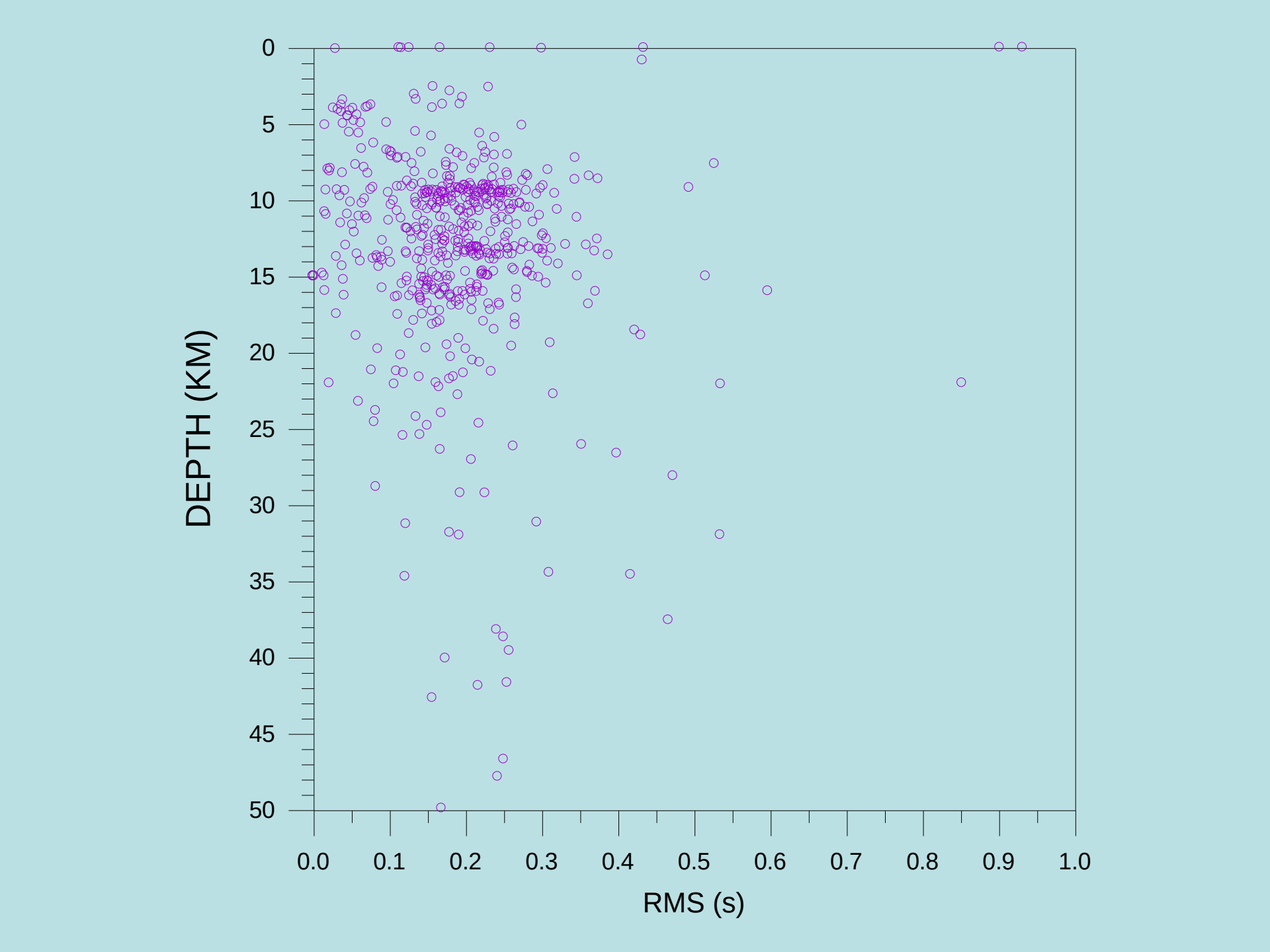
PRE1
25304
-25304
APRI
LOCALIZZA

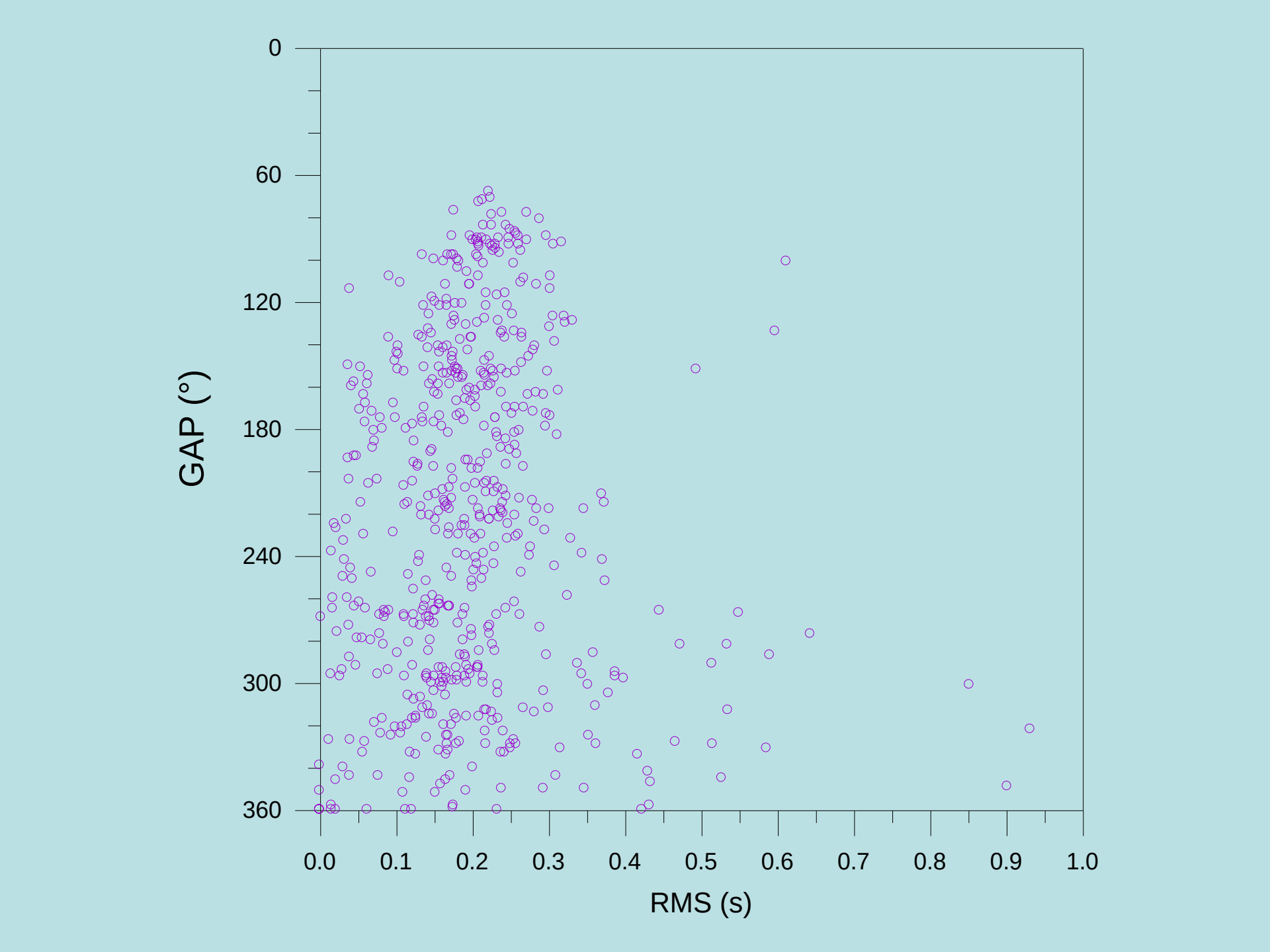

frmPicking
2657
2654
4204
4178
3288
2598
BRS1
20 sec.
Da:
2
A:
15
Filtro C0
Filtro C1
Filtro C2
BRS1 I P C 0 07/02/2009 2.32.02 592 E Sq 0 5 632 30
07/02/2009 02.31 54,752


2006-2007
LATITUDINE NORD
43
42
12
13
14
15
16
LONGITUDINE EST

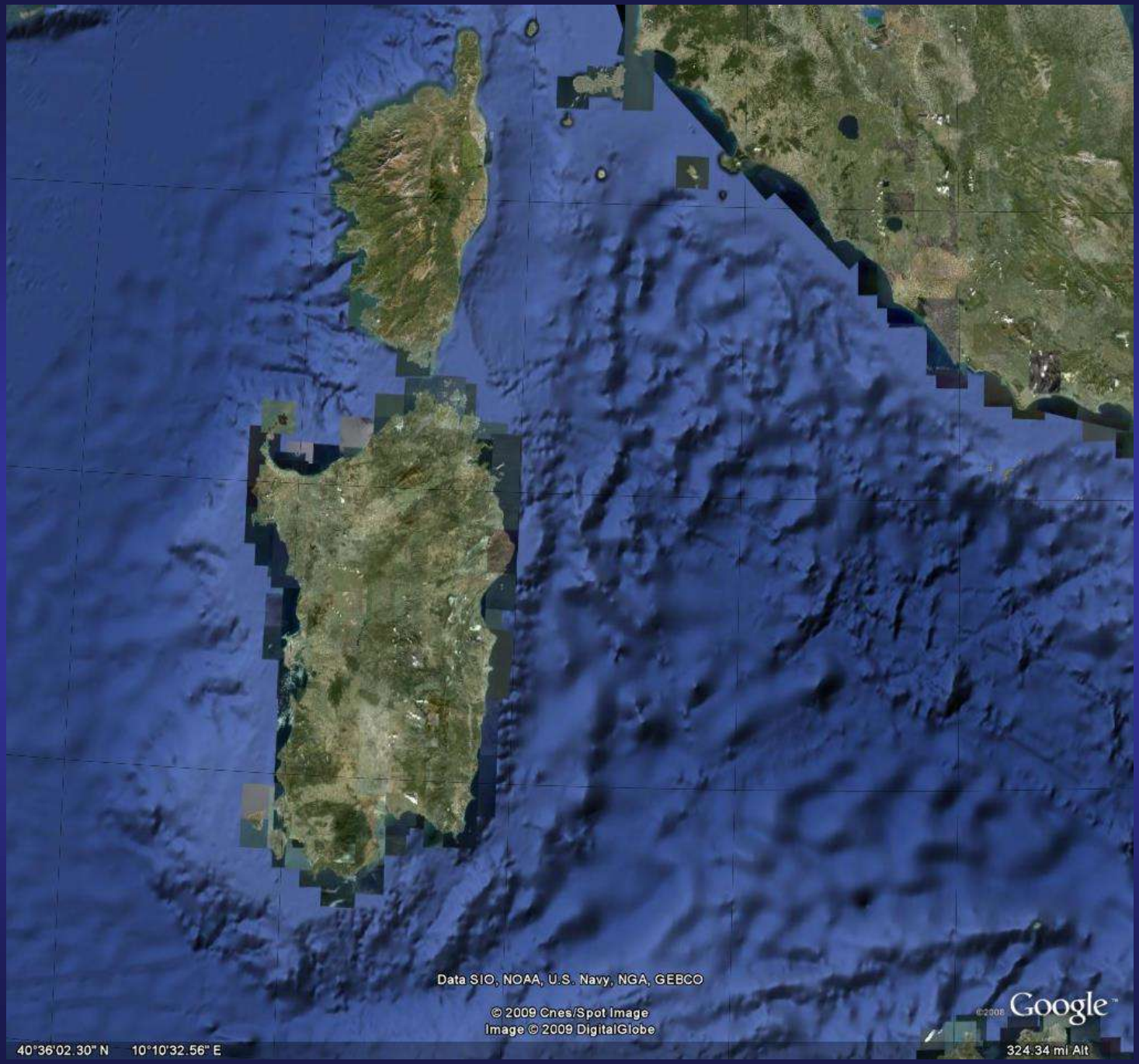

DEPTH (KM)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
41
42
43
44
LATITUDE NORD (°)

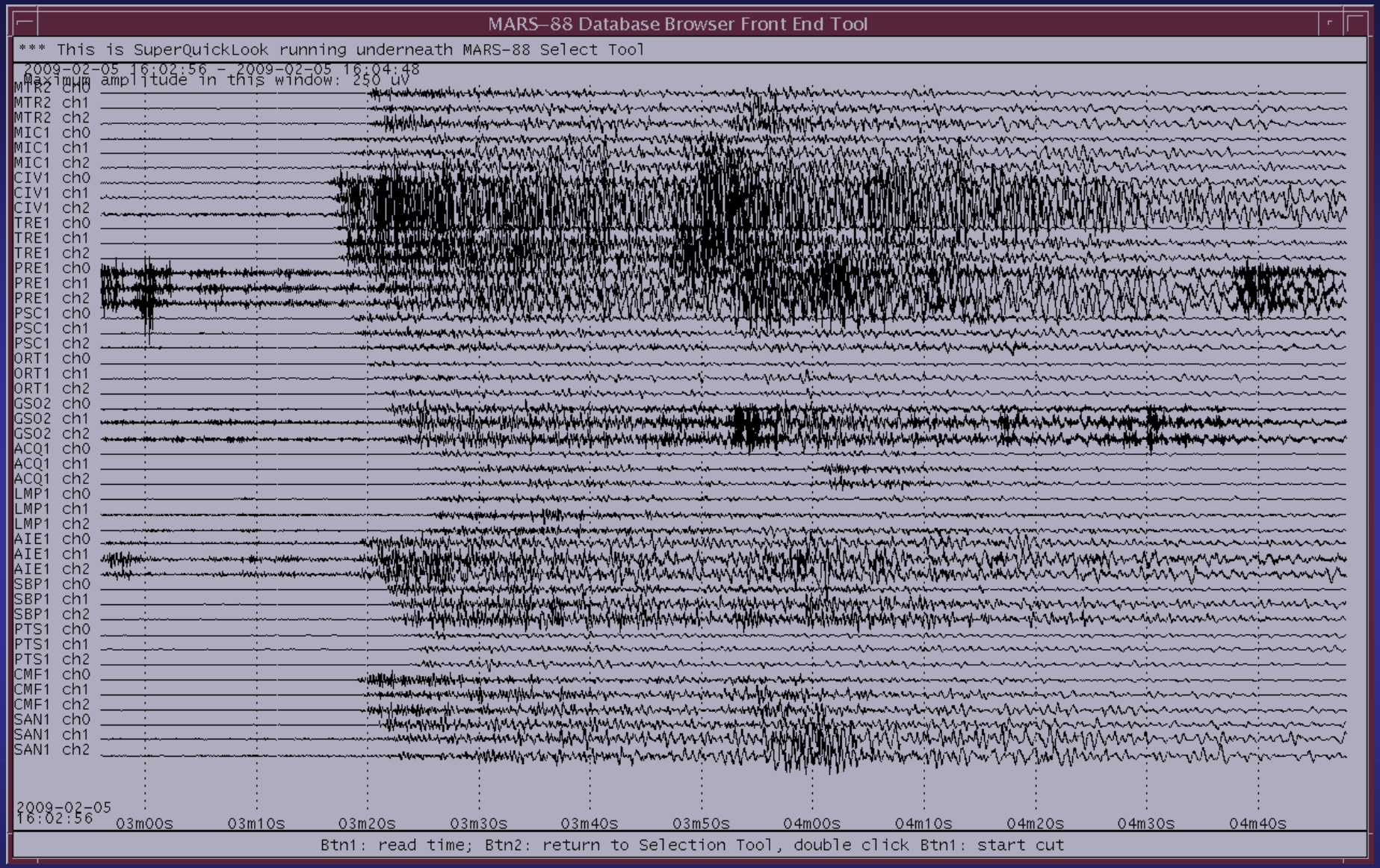

PHASE NUMBERS
35
30
25
20
15
10
5
0
2006
2007
2008
TIME

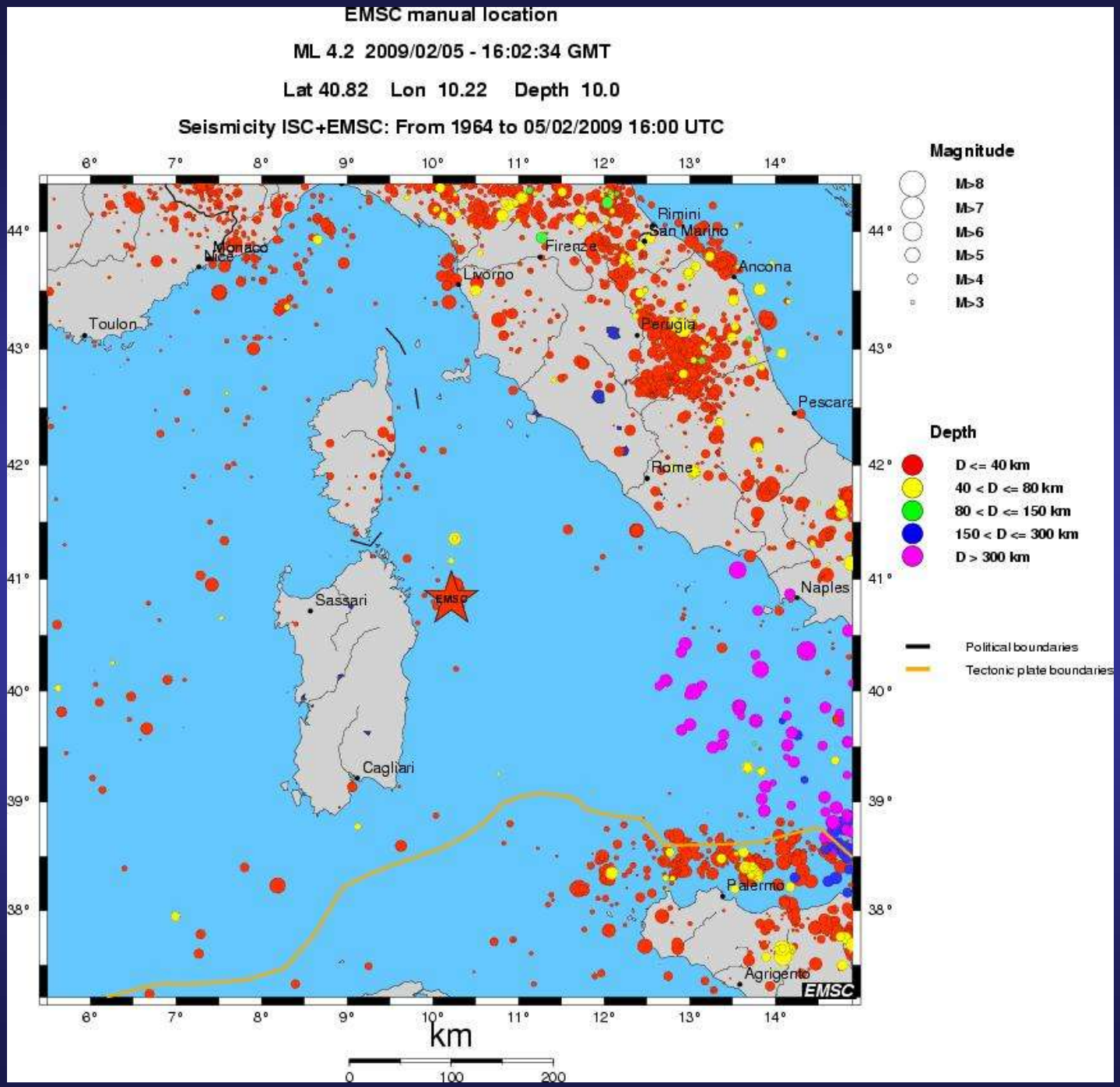

DEPTH (KM)
0
5
10
15
20
25
30
35
40
45
50
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
RMS (s)

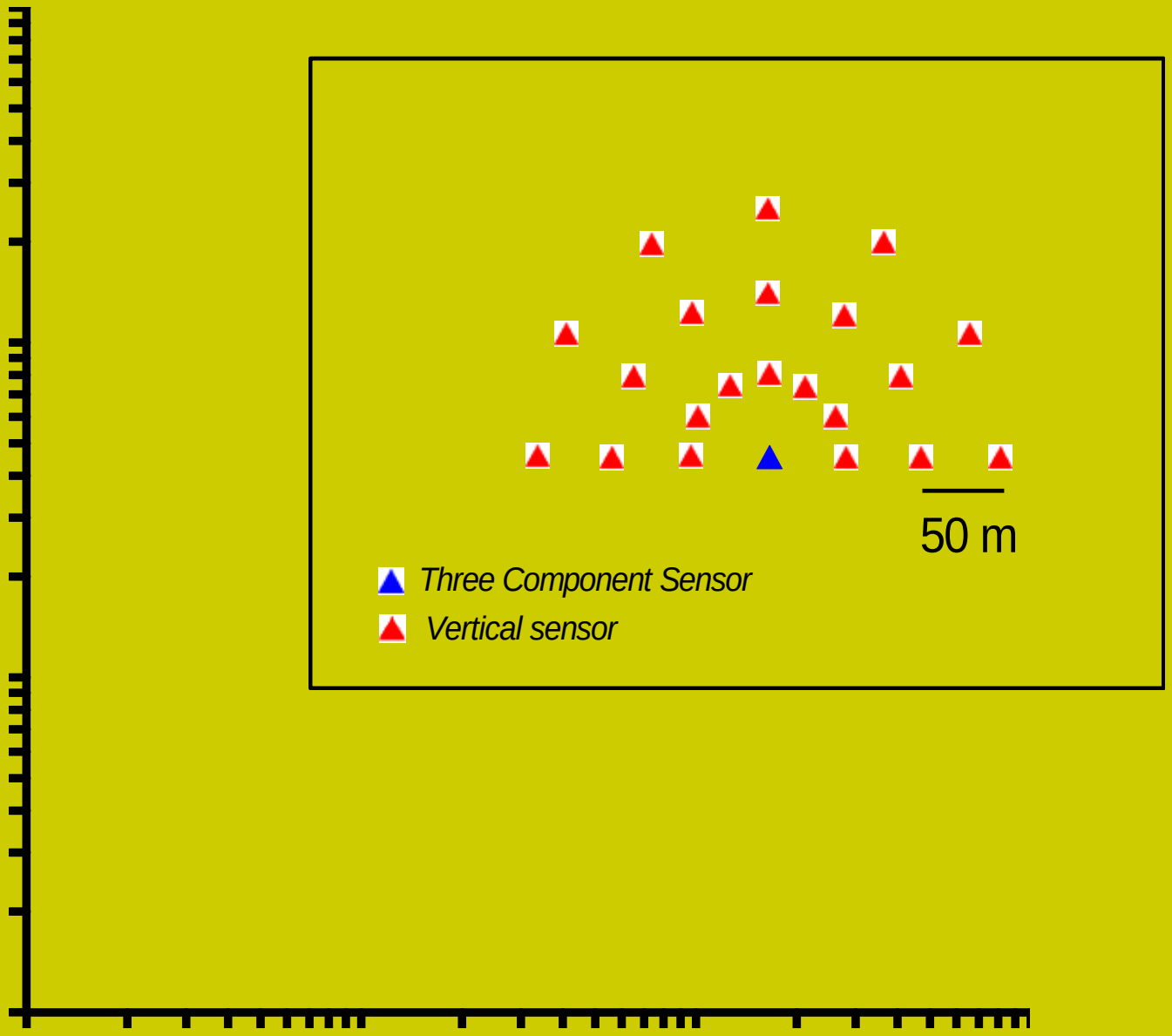

0
60
120
180
240
300
360
GAP (°)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
RMS (s)


10
15
45°
43°
100 km
5.0-7.0 Ml
4.0-5.0 Ml
3.0-4.0 Ml
2.0-3.0 Ml
0.0-2.0 Ml


Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Cnes/Spot Image
Image © 2009 DigitalGlobe
©2008 Google
40°36'02.30" N 10°10'32.56" E
324.34 mi Alt


MARS-88 Database Browser Front End Tool
*** This is SuperQuickLook running underneath MARS-88 Select Tool
2009-02-05 16:02:56 - 2009-02-05 16:04:48
Maximum amplitude in this window: 250 uV
MTR2 ch0
MTR2 ch1
MTR2 ch2
MIC1 ch0
MIC1 ch1
MIC1 ch2
CIV1 ch0
CIV1 ch1
CIV1 ch2
TRE1 ch0
TRE1 ch1
TRE1 ch2
PRE1 ch0
PRE1 ch1
PRE1 ch2
PSC1 ch0
PSC1 ch1
PSC1 ch2
ORT1 ch0
ORT1 ch1
ORT1 ch2
GSO2 ch0
GSO2 ch1
GSO2 ch2
ACQ1 ch0
ACQ1 ch1
ACQ1 ch2
LMP1 ch0
LMP1 ch1
LMP1 ch2
AIE1 ch0
AIE1 ch1
AIE1 ch2
SBP1 ch0
SBP1 ch1
SBP1 ch2
PTS1 ch0
PTS1 ch1
PTS1 ch2
CMF1 ch0
CMF1 ch1
CMF1 ch2
SAN1 ch0
SAN1 ch1
SAN1 ch2
2009-02-05
16:02:56
03m00s
03m10s
03m20s
03m30s
03m40s
03m50s
04m00s
04m10s
04m20s
04m30s
04m40s
Btn1: read time; Btn2: return to Selection Tool, double click Btn1: start cut


EMSC manual location
ML 4.2 2009/02/05 - 16:02:34 GMT
Lat 40.82 Lon 10.22 Depth 10.0
Seismicity ISC+EMSC: From 1964 to 05/02/2009 16:00 UTC
Magnitude
M>8
M>7
M>6
M>5
M>4
M>3
Depth
D <= 40 km
40 < D <= 80 km
80 < D <= 150 km
150 < D <= 300 km
D > 300 km
Political boundaries
Tectonic plate boundaries
Monaco
Nice
Toulon
Livorno
Firenze
Rimini
San Marino
Ancona
Perugia
Pescara
Rome
Naples
Sassari
Cagliari
Palermo
Agrigento
EMSC
km
0
100
200


50 m
Three Component Sensor
Vertical sensor