The 1991 Mount Pinatubo eruption - or why the atmosphere contributes to the excitation of the Hum.

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Hum-Day München, 12. 9. 2014

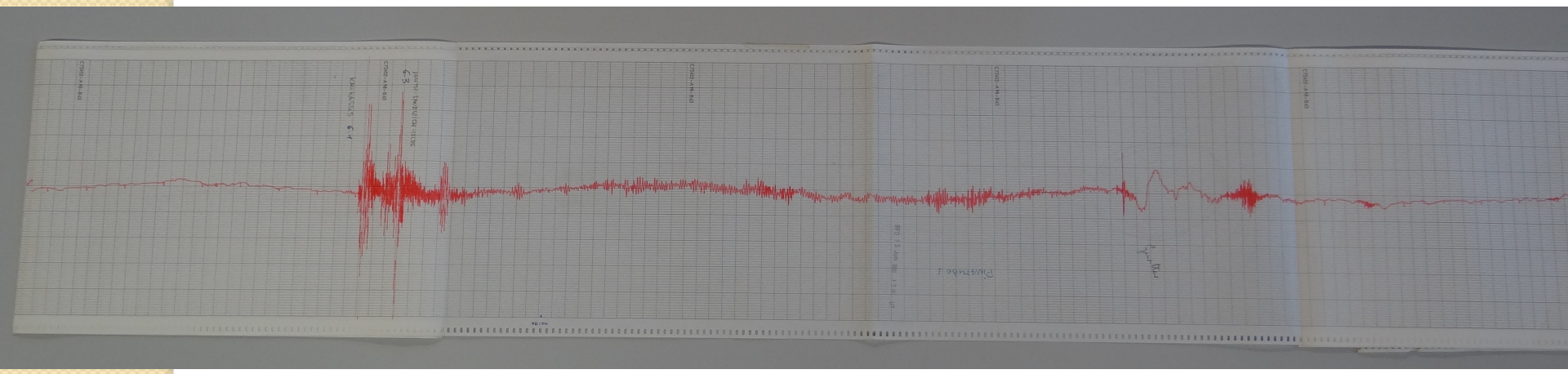
Overview

- The strip-chart recording which triggered our research
- Seismic signature of the 1991 Pinatubo eruption
- Characterizing the Pinatubo source
- Remaining Pinatubo mystery: phase coherence of radiated seismic energy

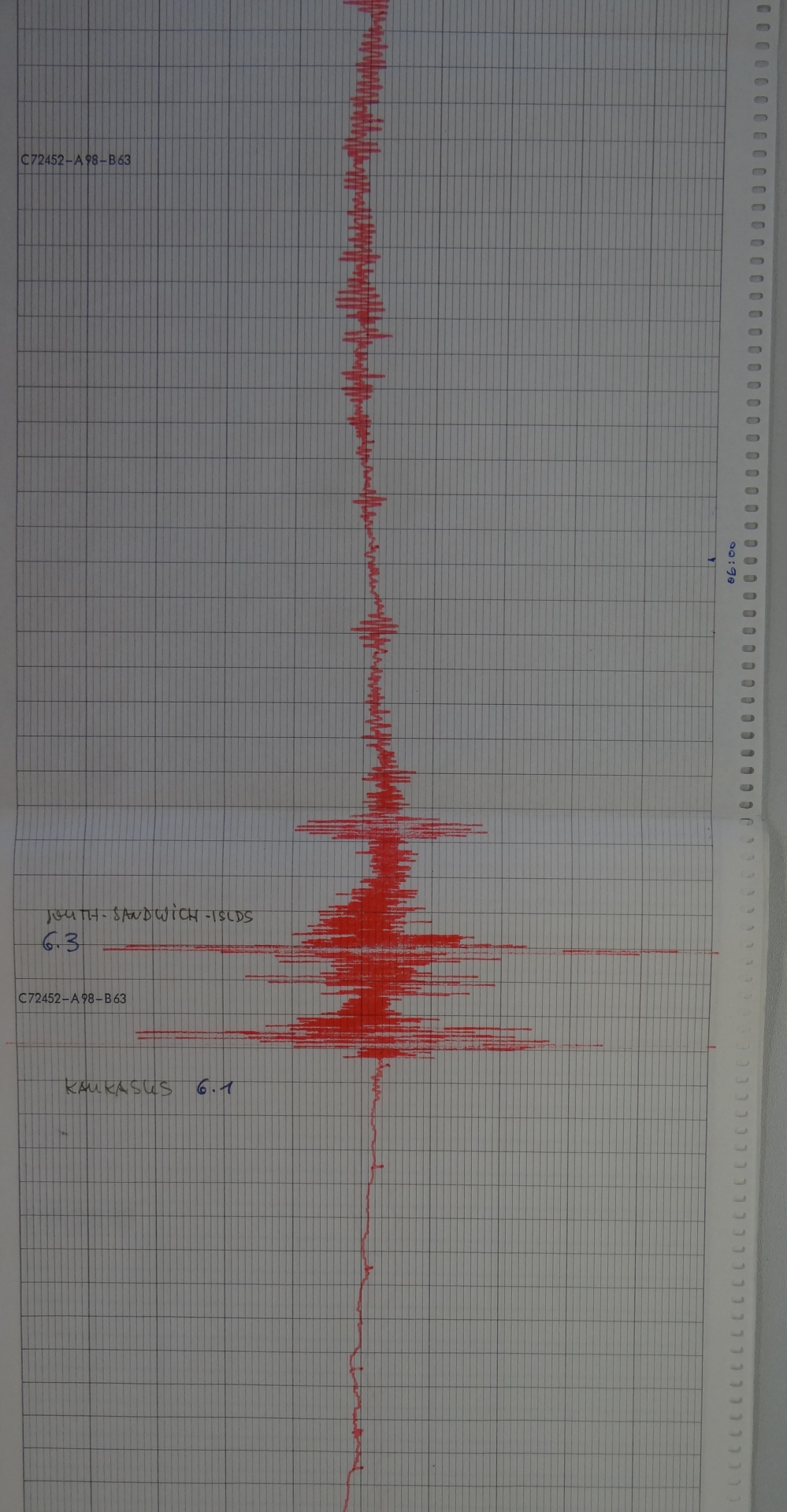
- Pinatubo and the evidence for atmospheric Hum excitation

LaCoste-Romberg ET-19 gravimeter - strip chart record of Mount Pinatubo eruption

- Mode channel: 5.5cm / μgal



- Time axis: 20min / division
- Y-axis: 2mm / division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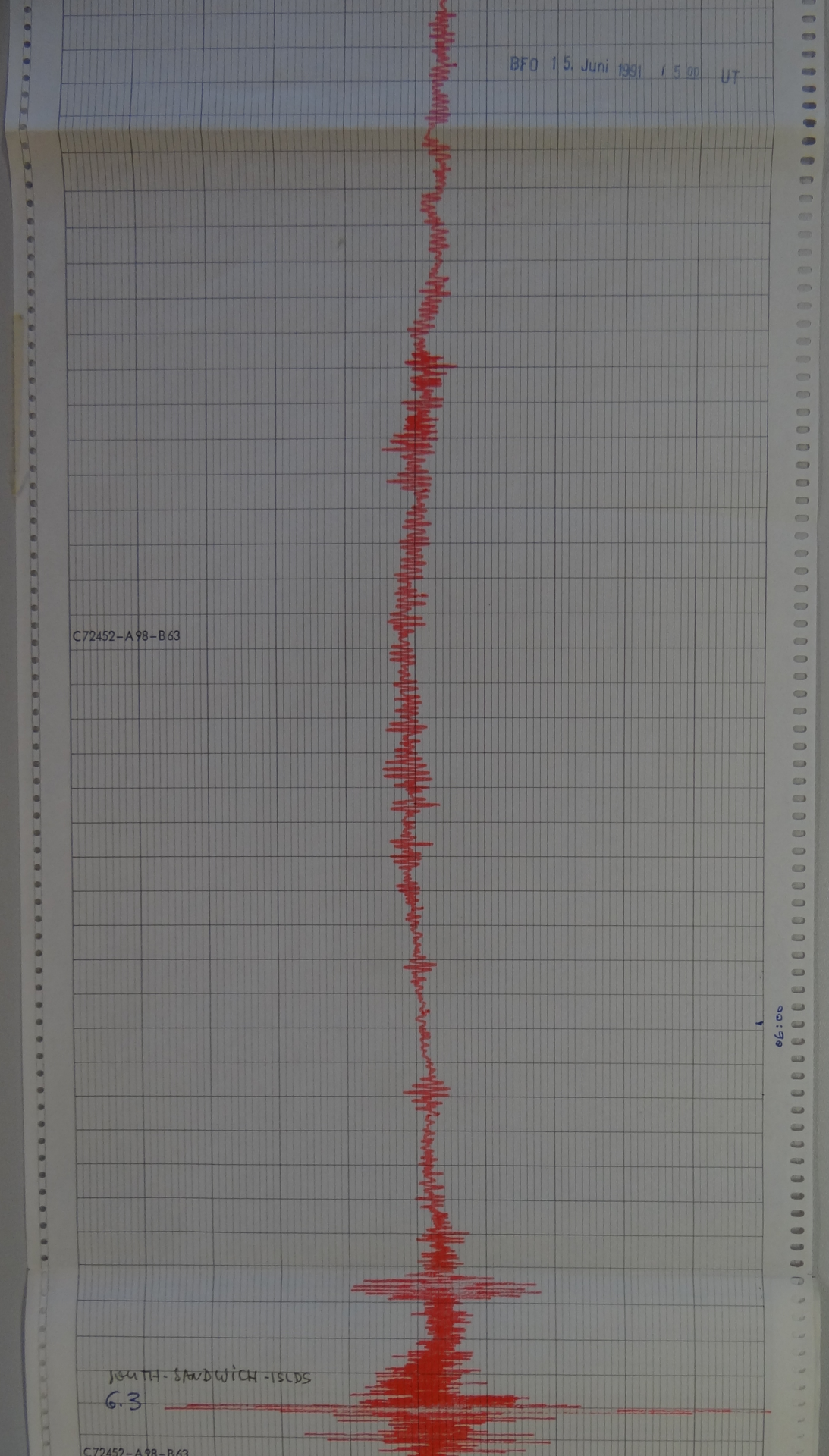
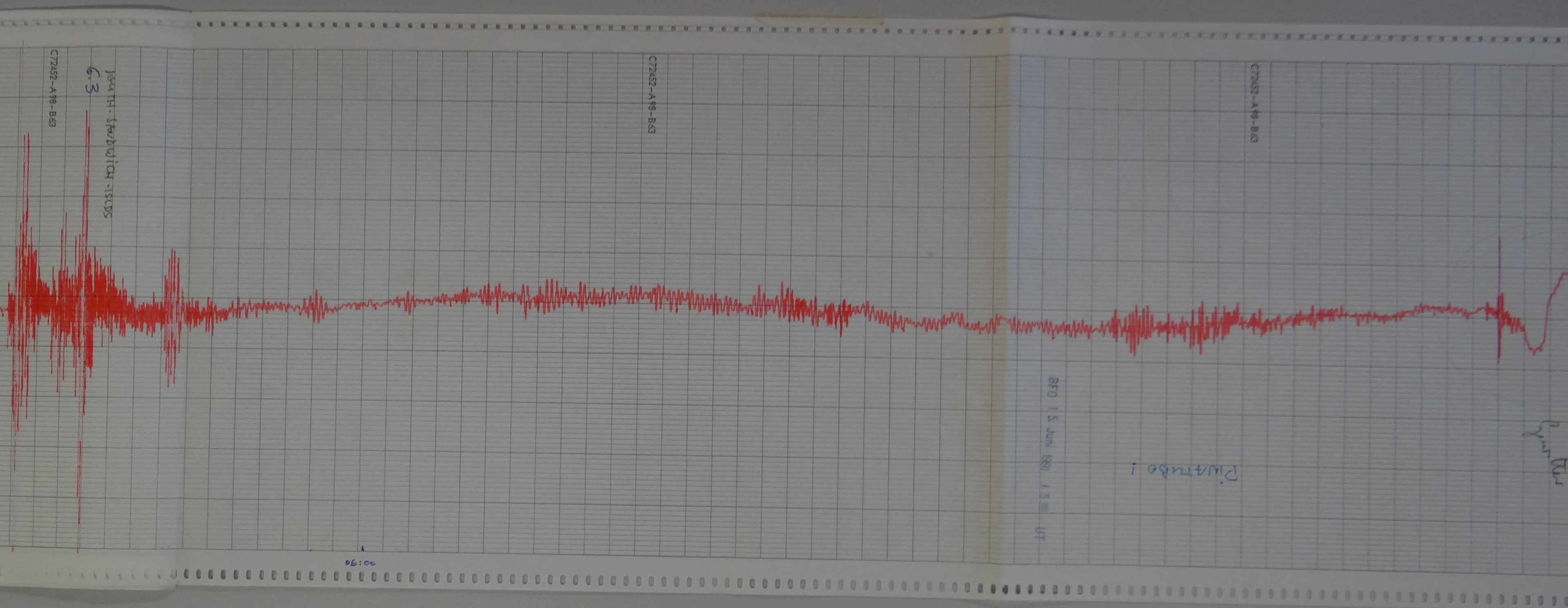
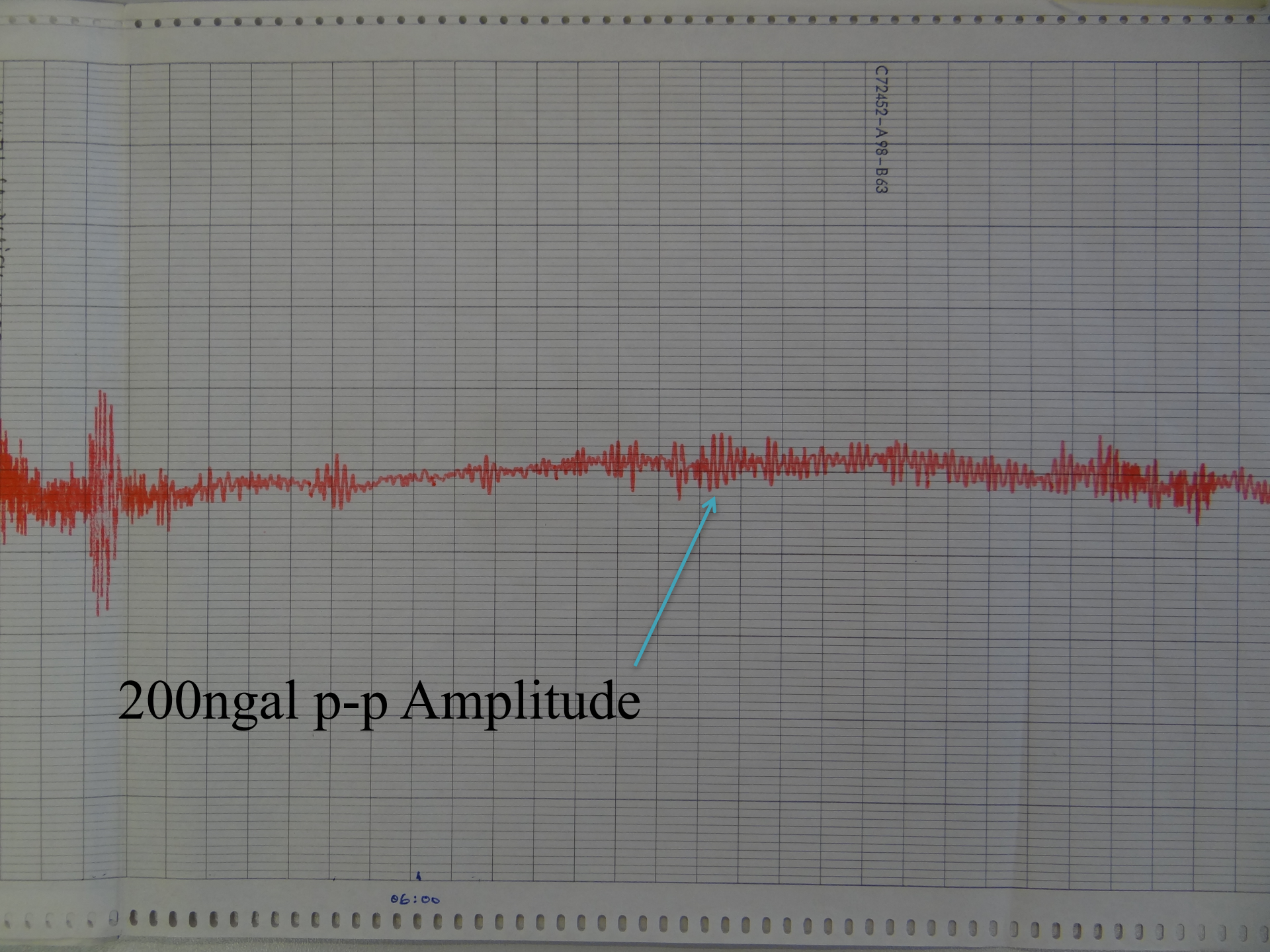
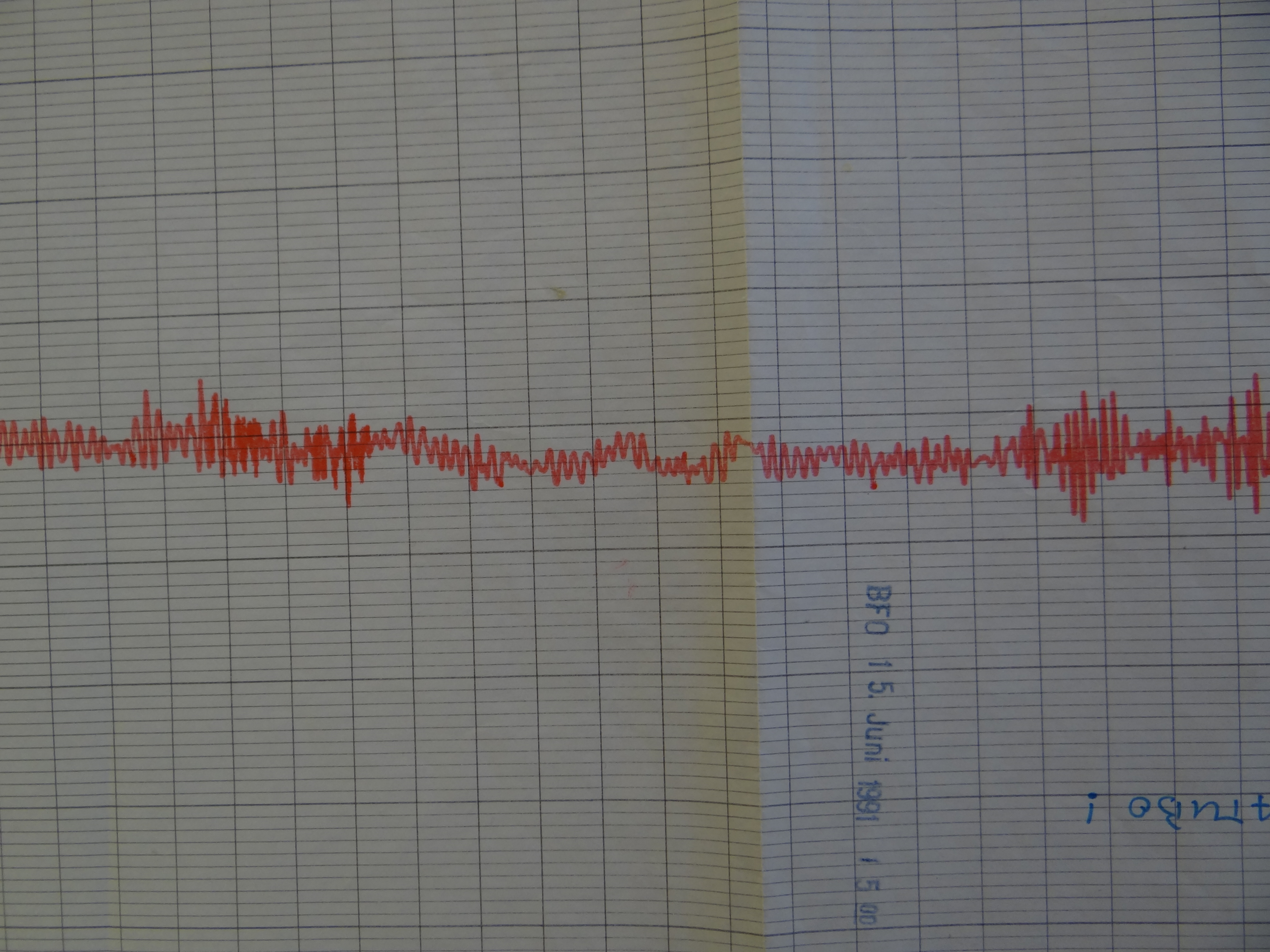
SOUTH-SANDWICH-ISLDS
6.3
C72452-A98-B63
KAUKASUS 6.1

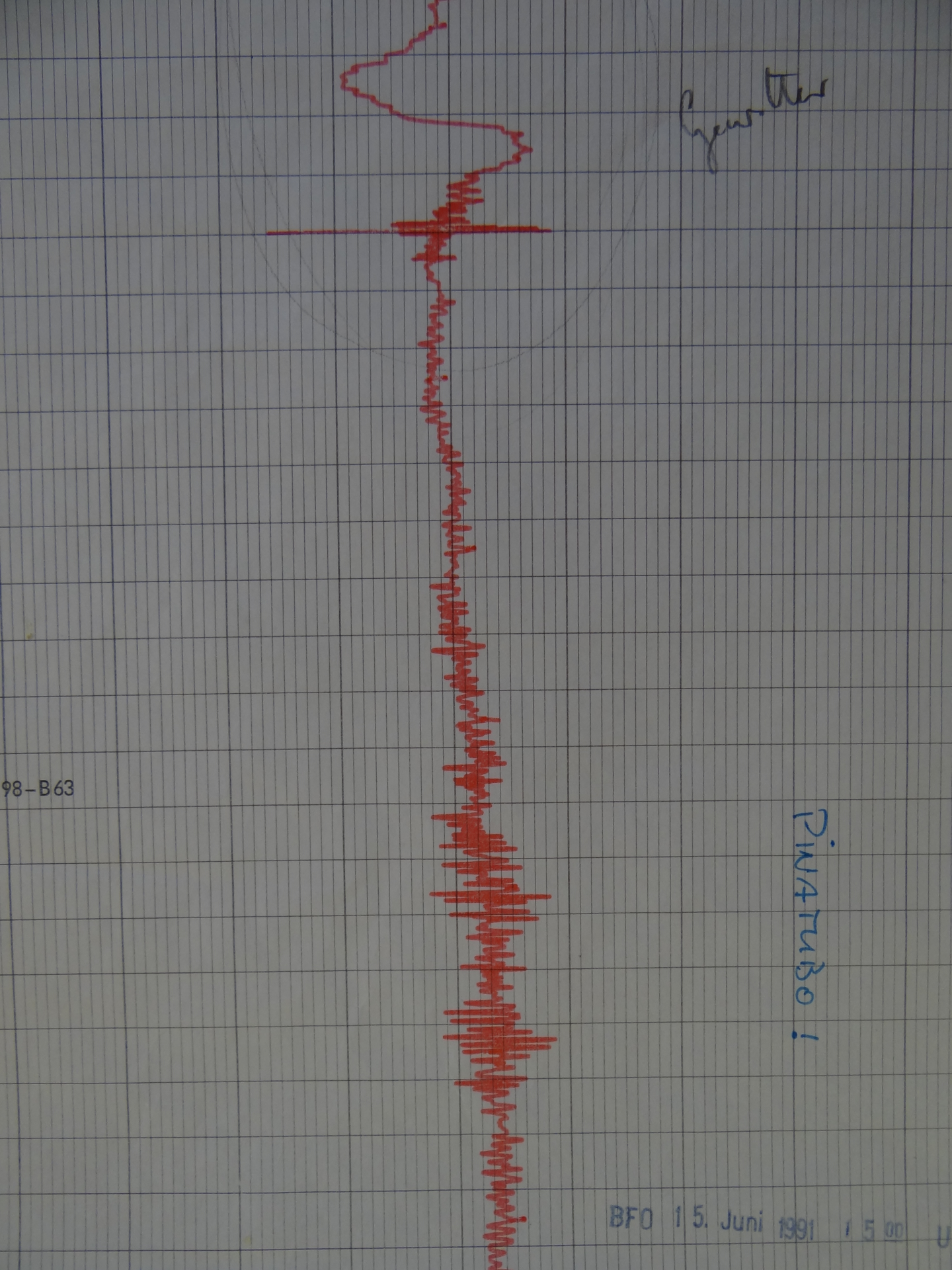

BFO 15. Juni 1991 15 00 UT
C72452-A98-B63
06:00
SOUTH-SANDWICH-ISLDS
6.3
C72452-A98-B63

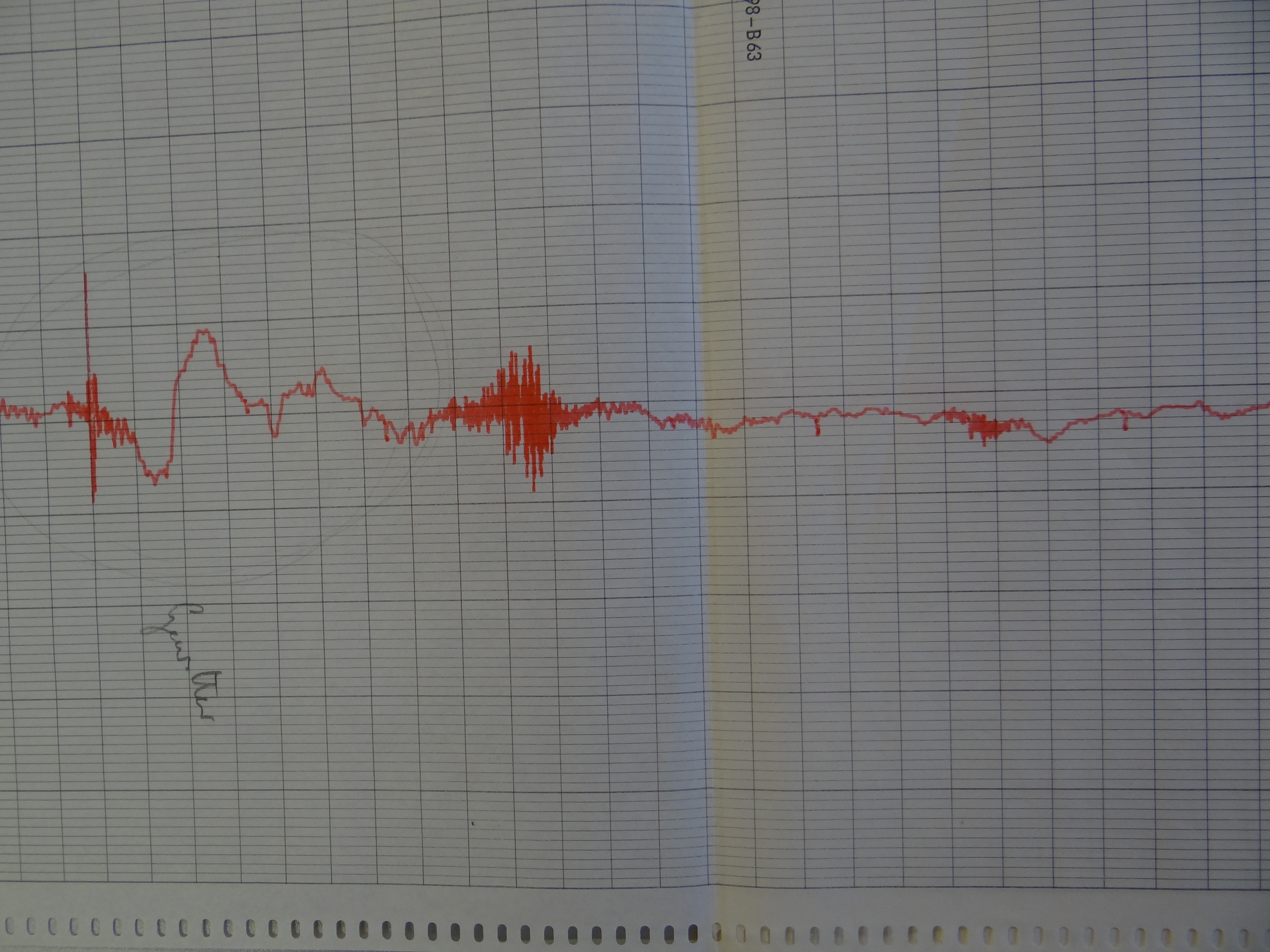


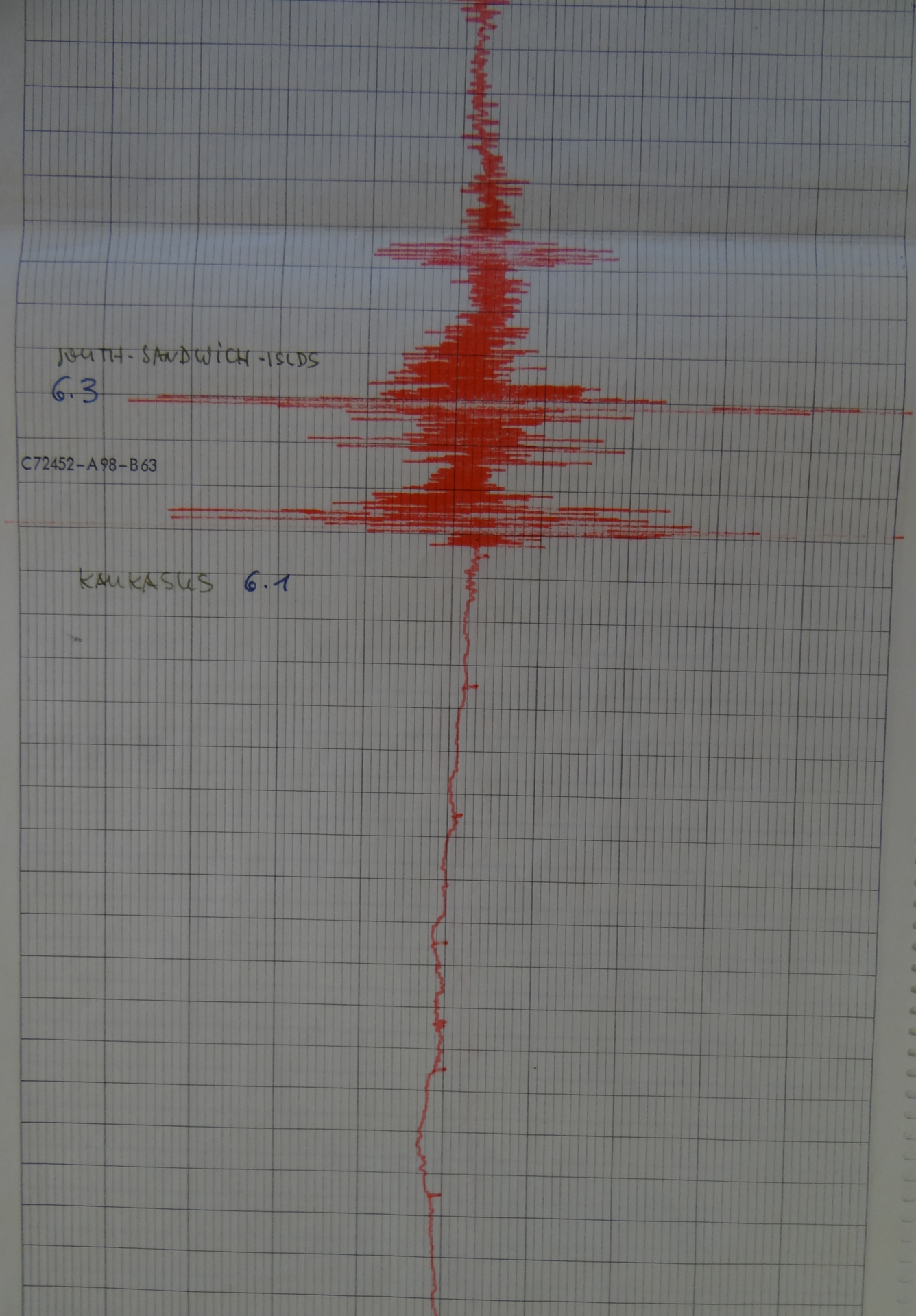
C72452-A98-B63
SOUTH-SANDWICH-ISLDS
6.3
C72452-A98-B63
C72452-A98-B63
06:00
BFO 15 Juni 1981
UT
Pinatubo !


C72452-A98-B63
200ngal p-p Amplitude
06:00


BFO 15. Juni 1991 15 00

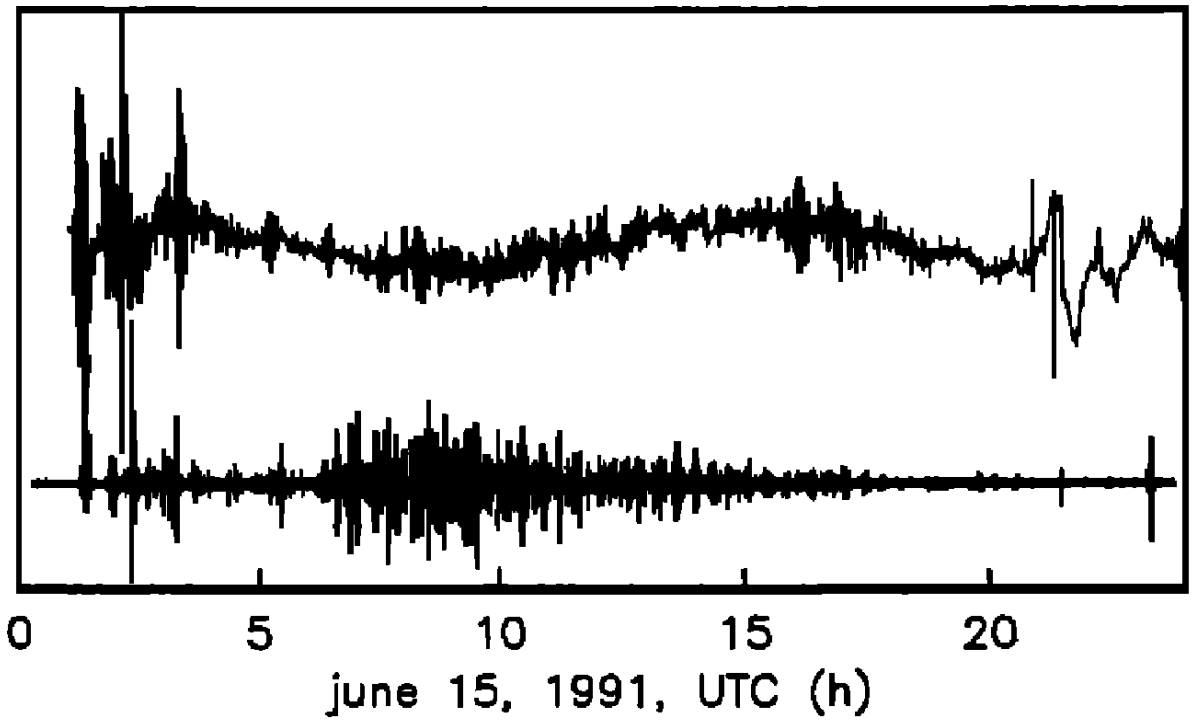

98-B63
PINATUBO !
BFO 15. Juni 1991 15 00


B63

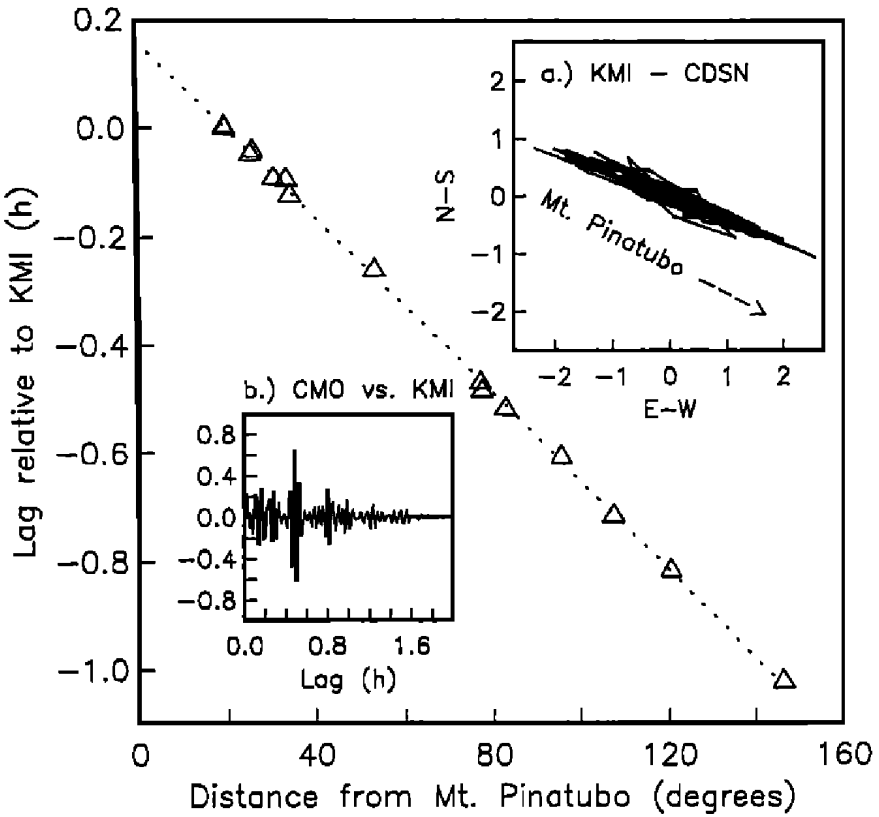

SOUTH-SANDWICH-ISLDS
6.3
C72452-A98-B63
KAUKASUS 6.1

- The signal between 06:00 and 14:00 on June 15, 1991 was not detected by any seismological agency
- Amplitude: >200ngal
- Spectrum: bi-chromatic: 3.7 & 4.4 mHz
- Not a short, transient source with its distinct Rayleigh wave packets

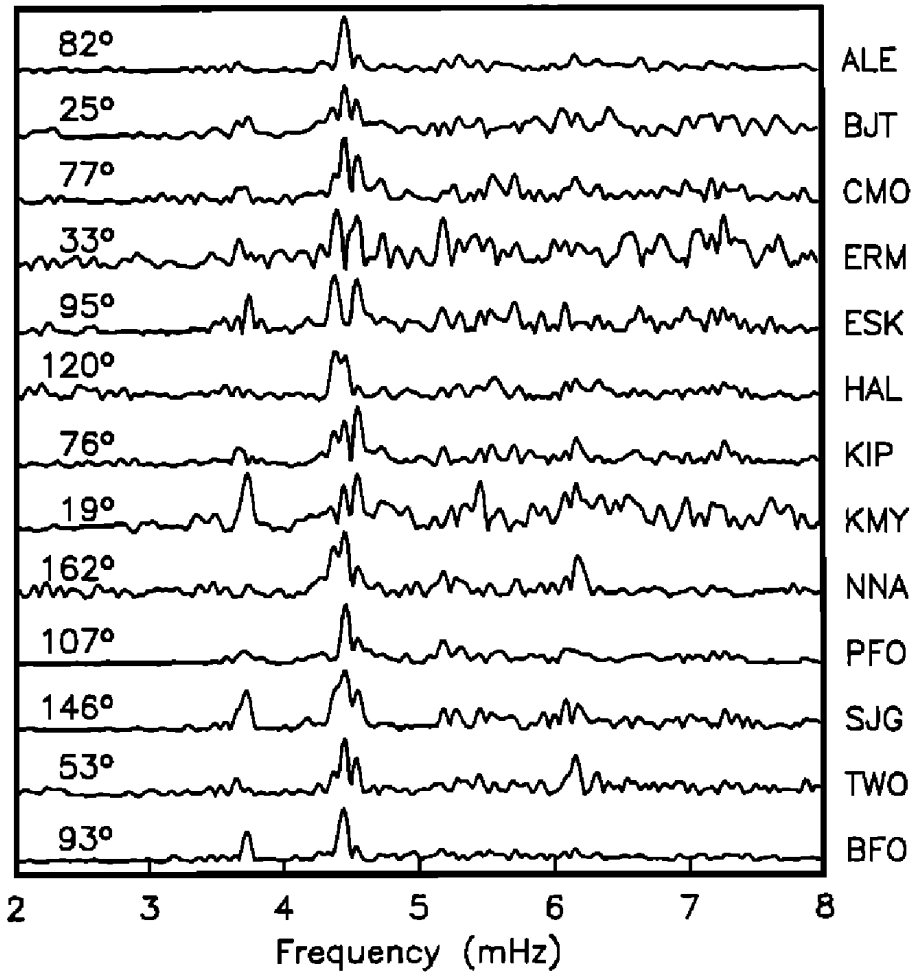
digital record

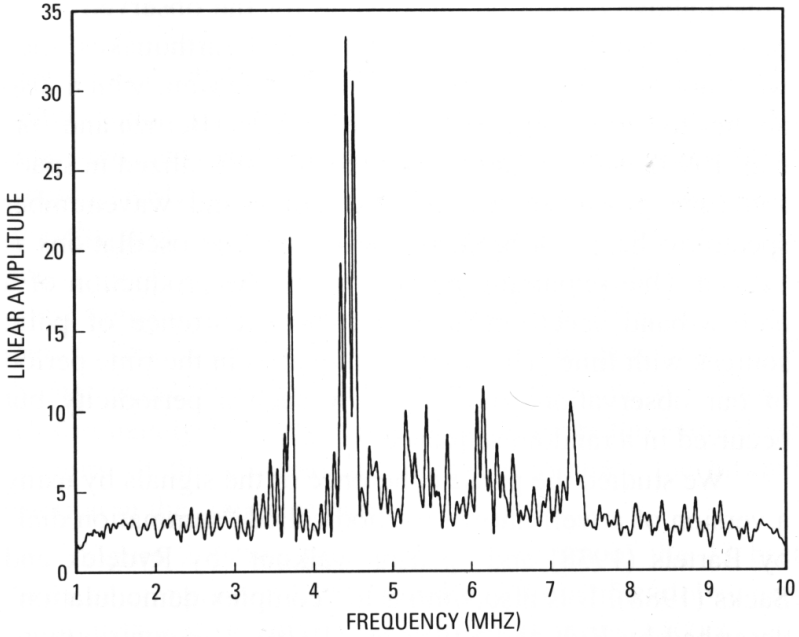


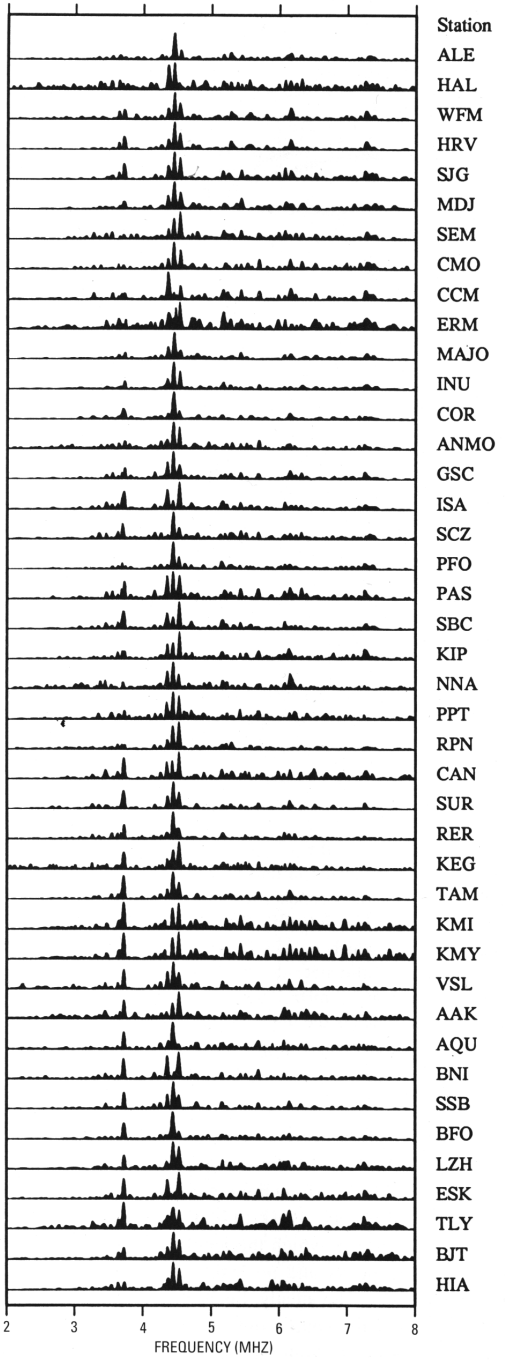
Identifying Pinatubo as the source of the low-frequency signal



Spectra of gravimeter records




LINEAR AMPLITUDE
FREQUENCY (MHZ)
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10


Station
ALE
HAL
WFM
HRV
SJG
MDJ
SEM
CMO
CCM
ERM
MAJO
INU
COR
ANMO
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ISA
SCZ
PFO
PAS
SBC
KIP
NNA
PPT
RPN
CAN
SUR
RER
KEG
TAM
KMI
KMY
VSL
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AQU
BNI
SSB
BFO
LZH
ESK
TLY
BJT
HIA
2
3
4
5
6
7
8
FREQUENCY (MHZ)

Source:

location:

- Philippines (cross correlation analysis)

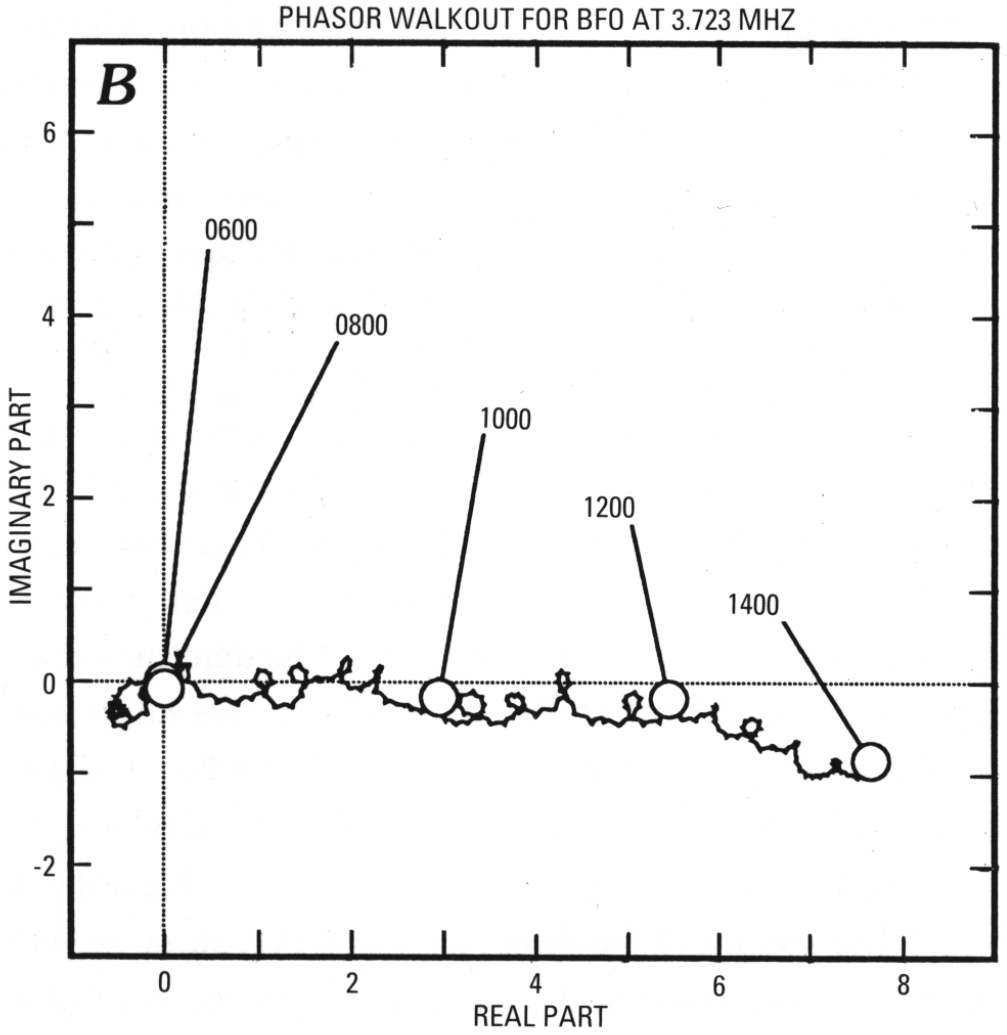
signal:

- Rayleigh waves (polarization of particle motion, group velocity)

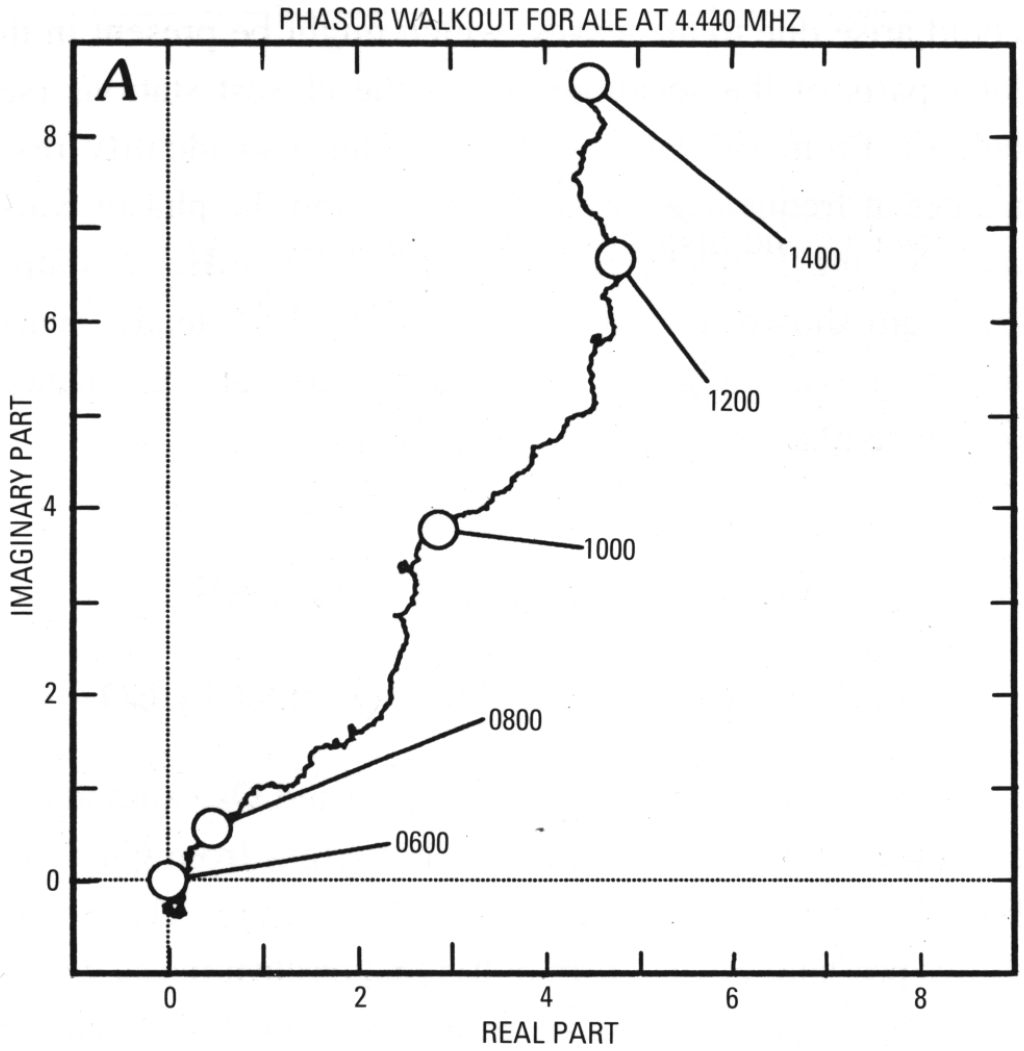
spectrum:

- Predominantly bi-chromatic: 3.7 and 4.4 mHz

Phasor walk: BFO @ 3.723 mHz



Phasor walk: ALE @ 4.44 mHz



Phasor walk:

we observe:

- at 3.7 and 4.4 mHz the Pinatubo signal is phase coherent for 8 hrs.

we infer:

- The source must have radiated **in phase** for the entire time of the eruption.
- This is at odds with the view that the eruption is a random sequence of explosions.

we speculate:

- a feed-back mechanism between the erupting volcano and the oscillating atmosphere must have existed to modulate the eruption process.
- We lack near-field data to test this hypothesis.

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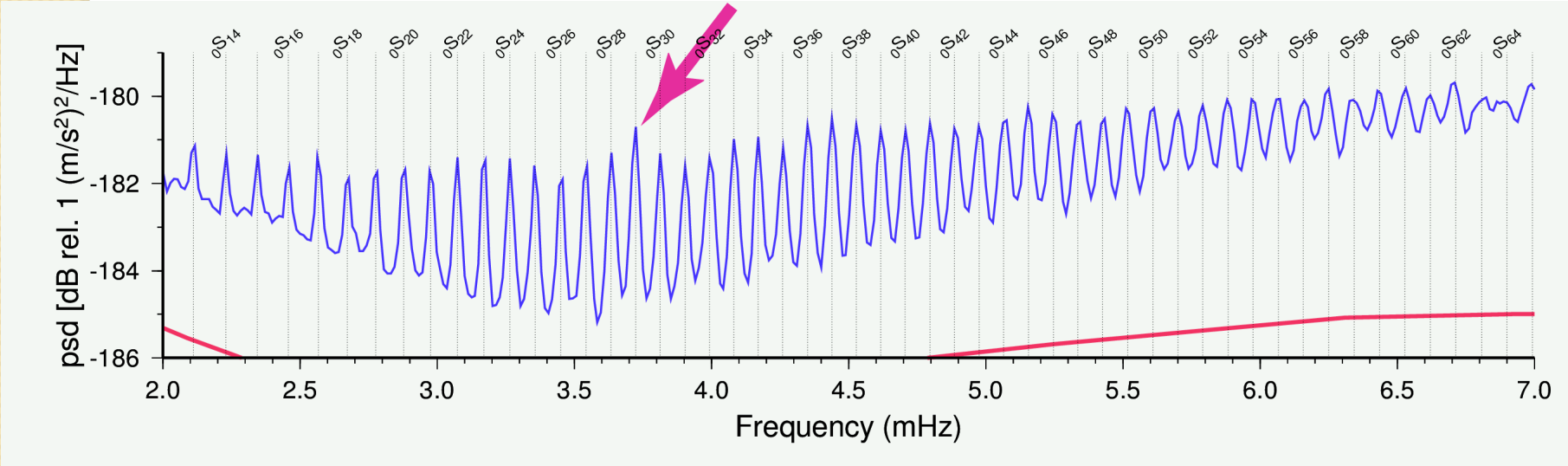
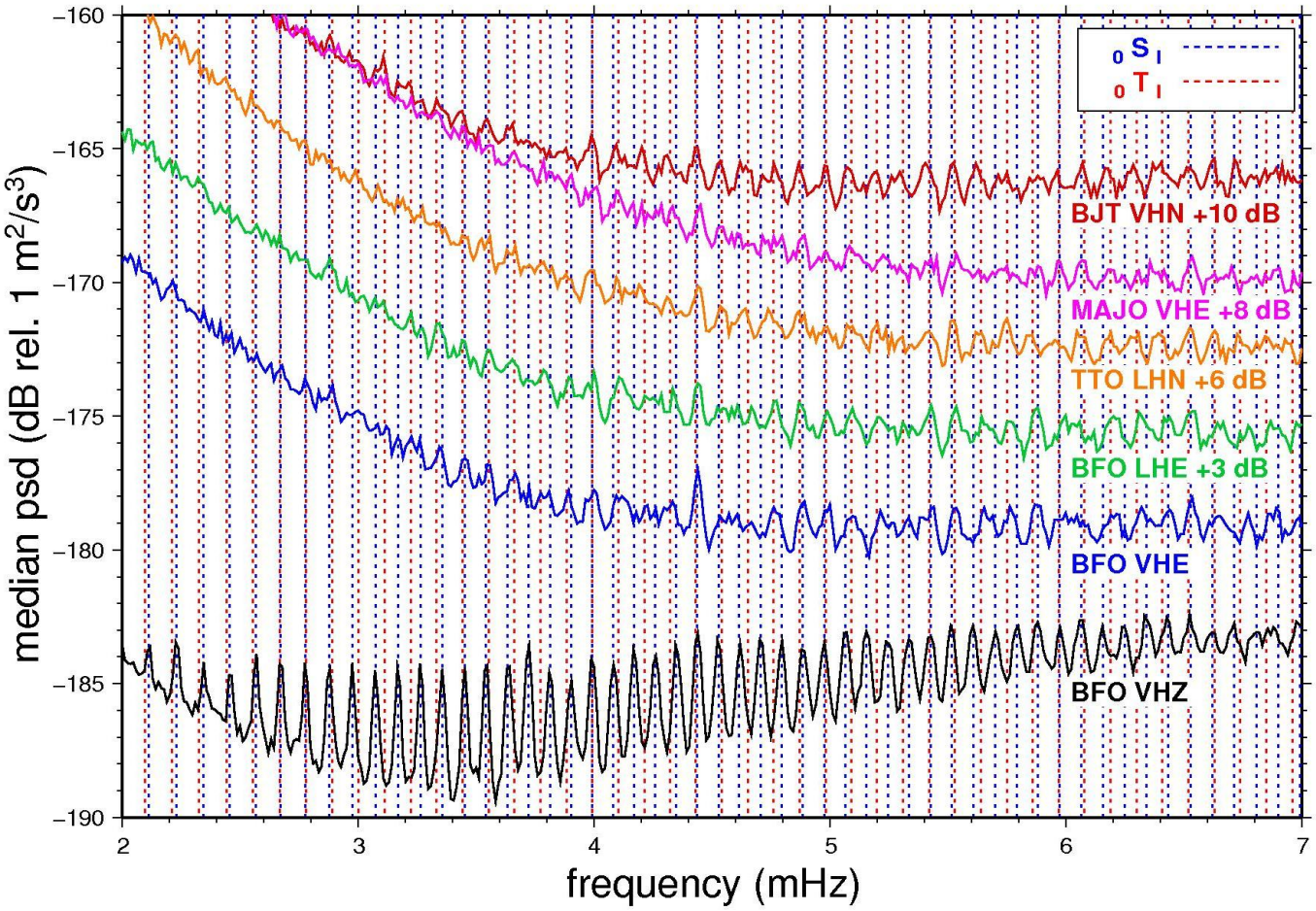
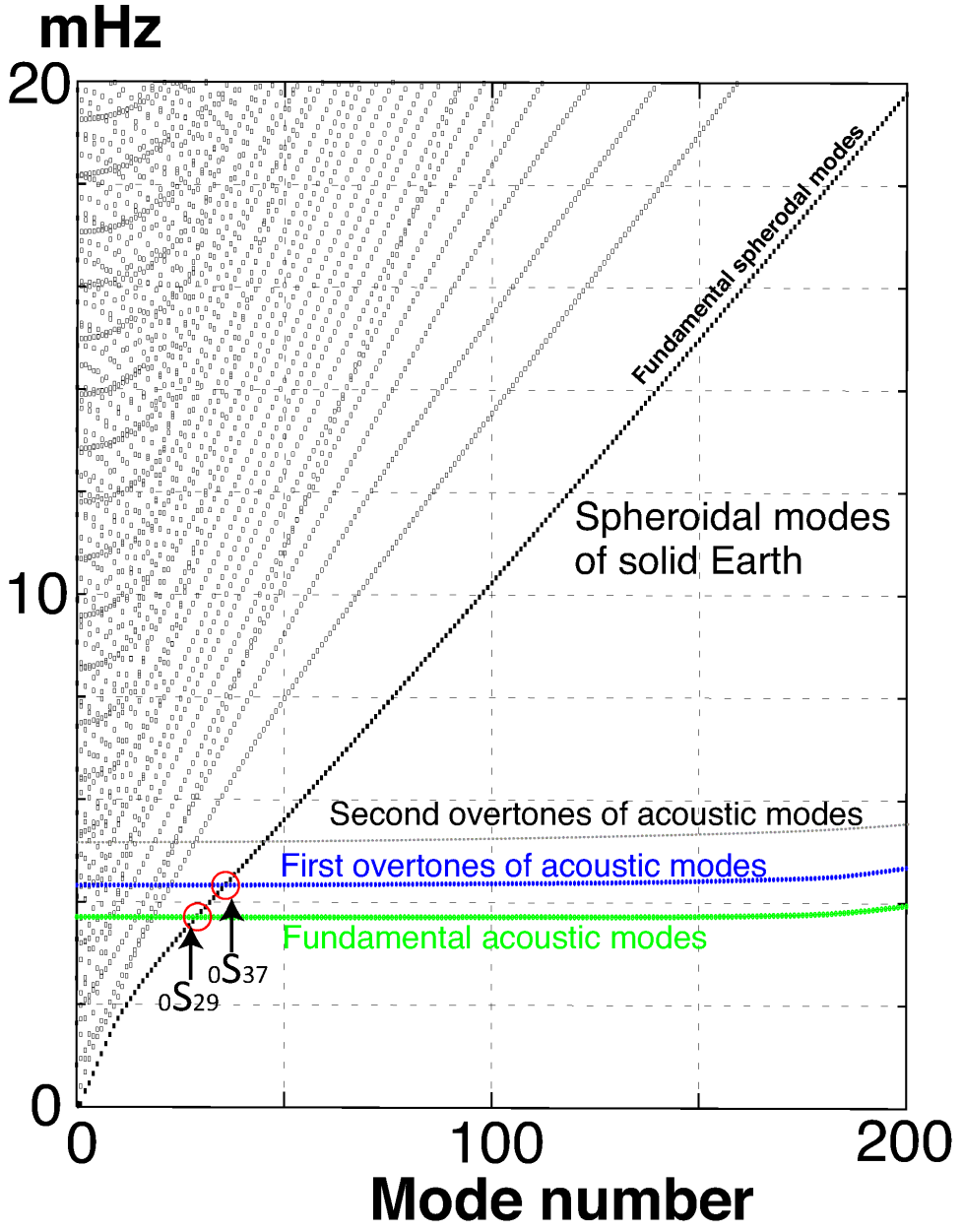
Vertical hum spectrum: amplification at 3.7mHz



Hum spectra: amplification at 3.7 mHz



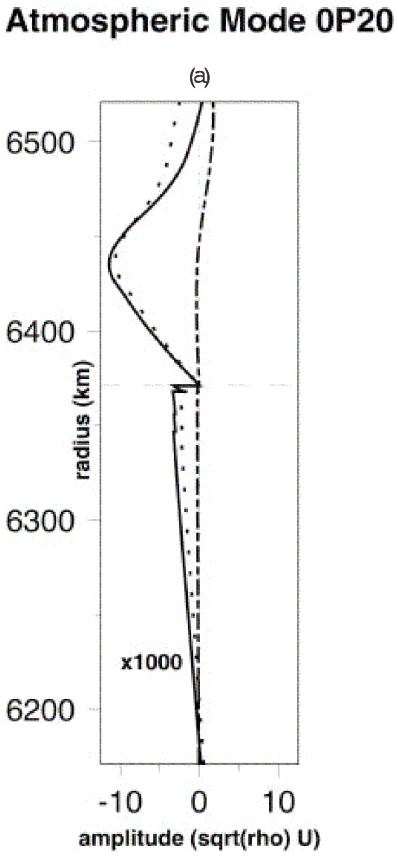
Normal modes of an Earth with an atmosphere



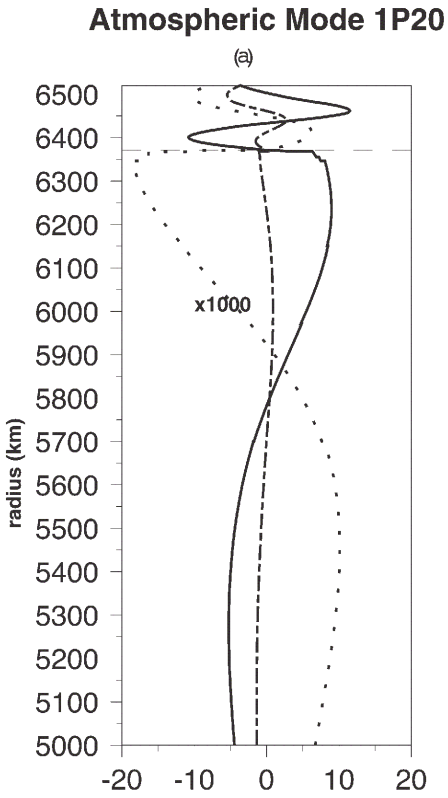
(Nishida, 2013)

Vertical displacement eigenfunctions of coupled modes

3.7mHz



4.4mHz



(Lognonné et al, 1998)

Summary

1. In the aftermath of the eruption of Mount Pinatubo the resonant coupling of the atmosphere and the solid Earth near 3.7mHz and 4.4 mHz was observed for the first time.
2. These two frequencies correspond to acoustic modes of the atmosphere: 3.7mHz is a fundamental mode while 4.4mHz is the first overtone.
3. The fact that the vertical Hum is amplified at 3.7 and 4.4 mHz by ~20% is interpreted as evidence for atmospheric Hum excitation.
4. The gravity signal observed after the Pinatubo eruption was more than 200 times larger than the vertical Hum.

References

Pinatubo:

1. Kanamori and Mori, GRL 1992.
2. Widmer and Zürn, GRL, 1992.
3. Widmer and Zürn, Fire and Mud, 1996.
4. Lognonné, Clévédé and Kanamori, GJI, 1998.

Hum excitation by the atmosphere:

1. Nishida, Kobayashi and Fukao, SCIENCE, 2000.
2. Tanimoto, 2001.

Acknowledgements

Station and network operators for the high-quality data:

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Funding:

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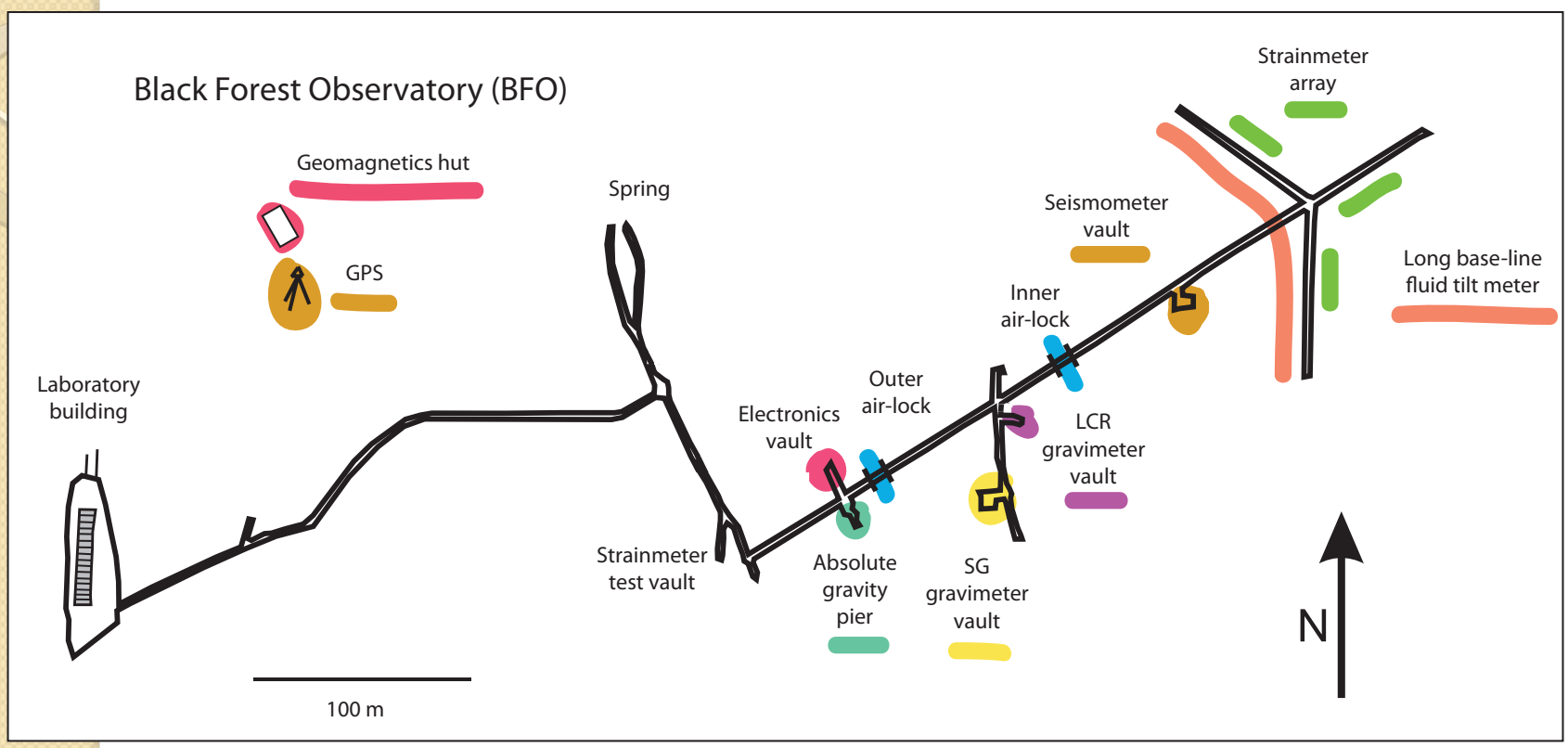
Black Forest Observatory (BFO)
Strainmeter array
Geomagnetics hut
Spring
Seismometer vault
Long base-line fluid tilt meter
GPS
Inner air-lock
Laboratory building
Outer air-lock
Electronics vault
LCR gravimeter vault
Strainmeter test vault
Absolute gravity pier
SG gravimeter vault
N
100 m