Memo

Albuquerque Seismological Laboratory
U.S. Geological Survey

April 14, 1998

To: Dr. Robert Kemerait, CTI
AFTAC/TT

From: Bob Hutt C.R.H.
USGS/ASL

Subject: Horizontal LP noise at GTSN stations, reduction using sand

Bob,

Here is a binder containing plots of 3-C data from the GTSN stations, as well as some GSN stations for comparison. These plots give some indication how much improvement might be expected if the broad band borehole seismometers (54000s) were surrounded with sand, as was done at VNDA.

Component names:

BHZ: broad band vertical (20 sps)
BHN: broad band north-south (20 sps)
BHE: broad band east-west (20 sps)
BH1: broad band horizontal #1 (not oriented north) (20 sps)
BH2: broad band horizontal #2 (orthogonal to BH1) (20 sps)

There is a set of three plots for each station:

1st one: ~1.5 hours of 20 sps data low pass filtered at .05 Hz (20 sec), plotted so that all three components have the same scale factor as the largest amplitude component. The vertical scale is in digitizer counts.

2nd one: The same 1.5 hours of 20 sps data, again low pass filtered at .05 Hz, but at a fixed magnification (peak full scale ~2.4E-06 meters/sec). All of these 2nd plots in each set may be compared directly with each other. If any waveform on these plots differs significantly from essentially a straight line, there may be room for improvement.

3rd one: A combination of power spectra and unfiltered waveform data containing the first 3276.8 seconds of data from the previous two plots. One can measure the difference (in dB) from the horizontal spectra to the vertical spectrum in the long period band (typically periods greater than 20

seconds) to get a rough idea how much improvement in the horizontal noise one could expect by adding sand around the borehole instrument. This is based on the following premises:

- Horizontal noise will never be lower than the vertical noise in this band, at a given site,
- Addition of sand will eliminate the air movement that causes the horizontal noise.

There is one set of plots for each GTSN station (two sets for VNDA), and then a few sets from GSN stations. There are two sets for VNDA, one from before the sand was added, and one after the sand was added. For the GSN stations, I've included some stations that are vault-type installations instead of borehole type, so you may compare noise between the two installation types. (One reason to install in deep boreholes is to reduce horizontal LP noise, so if the horizontals from a borehole are as noisy as a shallow vault type installation, then there is a problem.)

GTSN Stations:

BDFB: Not bad, but there's room for a few dB improvement.

BGCA: Sand should also help this one, but the BHE component appears as pulses, so may not be caused by air movement.

BOSA: Sand should help this one by ~10 to 15 dB at 100 seconds.

CPUP: Time segment is less than one hour in length, but it appears that sand would help the horizontal noise by perhaps 20 dB at 100 sec. Immediately after the new instrument was installed at CPUP (Feb 1998), the horizontals were quiet. Noise has slowly increased since that time. Before the instrument was damaged by lightning, this site had very noisy horizontals (about the same as VNDA before sand was added).

DBIC: Sand should help these horizontals by ~10-15 dB.

LBTB: This is 1 sps data rather than 20. Sand should improve the horizontal noise by ~10 dB.

LPAZ: The horizontal noise here is dominant at longer periods than in most cases, but sand should reduce the noise by 15-20 dB or more.

PLCA: Sand should reduce the horizontal noise by a few dB.

SBA: Although not technically a GTSN station, I've included this site because the instrument sits in a very shallow surface vault on Ross Island, Antarctica. Note that the horizontal long period noise here is quite high, but still lower than was VNDA before sand was added. (Note also that the 2nd plot of the set is plotted at 20,000 counts peak full scale, because instrument sensitivity is 20,000 v/m/s.)

VNDA (day 1998, 096): This first set of VNDA plots is after sand was added to the borehole. The horizontals are a few dB above the vertical at 100 seconds, but this is probably the best that can be done at this particular site with this particular instrument.

VNDA (day 1997, 223): This second set of VNDA plots is before sand was added to the borehole, and demonstrates the extremely high level of the horizontal noise in the LP band. Noise reduction achieved by adding sand (see previous set of plots) was ~30 dB at 100 seconds.

GSN stations: Note that the 2nd plot of each set uses 2400 counts full scale, corresponding to the nominal instrument sensitivity of 2400 v/m/s and resulting in a full scale in terms of ground velocity of ~2.4E-06 meters/sec.

ANMO (Albuquerque, NM): This instrument is installed in sand at a depth of 500 feet. The long term "drift" seen on the first plot of the set is due to the solid earth tide signal. It can be seen on this instrument (a model 54000I, for IRIS) because we do not use the 1500 second high pass filter normally installed by the manufacturer. (This same "drift" may be seen on some of the other GSN plots as well, for the same reason.) The PSD plot indicates that the BH2 component is very close to the BHZ in the LP band, whereas the BH1 component is a few dB noisier. This is probably indicative of an inherently noisier BH1 seismometer module or feedback electronics channel.

COLA (College, Alaska): A 54000I installed in sand. A look at the PSD indicates that the BH1 noise level is actually slightly lower than that of the BHZ at periods longer than about 40 seconds.

GUMO (Guam): A 54000I installed without sand. This is a case where adding sand probably would not help much (the horizontals are already fairly quiet).

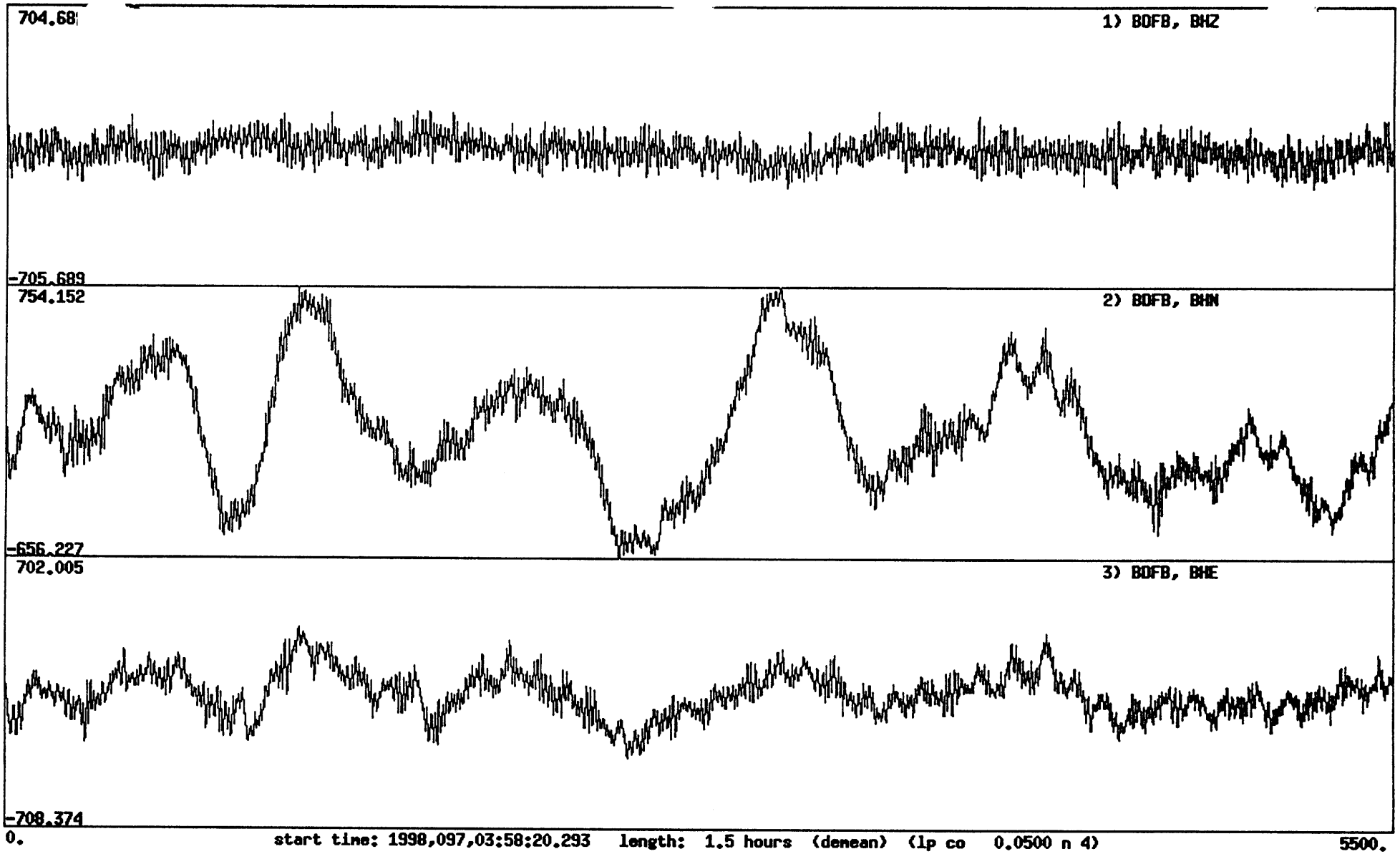
Added: SNZO (New Zealand): "No SAND" and "WITH SAND" plots added here.

SNZO (New Zealand): A 36000I installed in sand. Once again, we see that one of the horizontals is actually quieter than the vertical in a portion of the LP band.

TATO (Taipei, Taiwan): A 36000I installed without sand. Sand would probably help this one by a few dB.

HKT (Hockley, Texas): A set of Streckeisen STS-1 very broad band vault type instruments installed in a salt mine at a depth of ~1500 feet. Most of the noise on these horizontals is due to people and heavy equipment moving in the mine, as well as the slow creep of the salt trying to close the cavity that the instruments are in.

ULN (Ulaanbaatar, Mongolia): Another set of Streckeisen STS-1 very broad band vault type instruments, installed in the basement of a building in this case. One could fill the entire vault with sand and not improve this situation much because of the shallow depth below the surface and the presence of the building above the vault. These horizontals are fairly noisy, but not nearly as bad as was VNDA before the sand was added.



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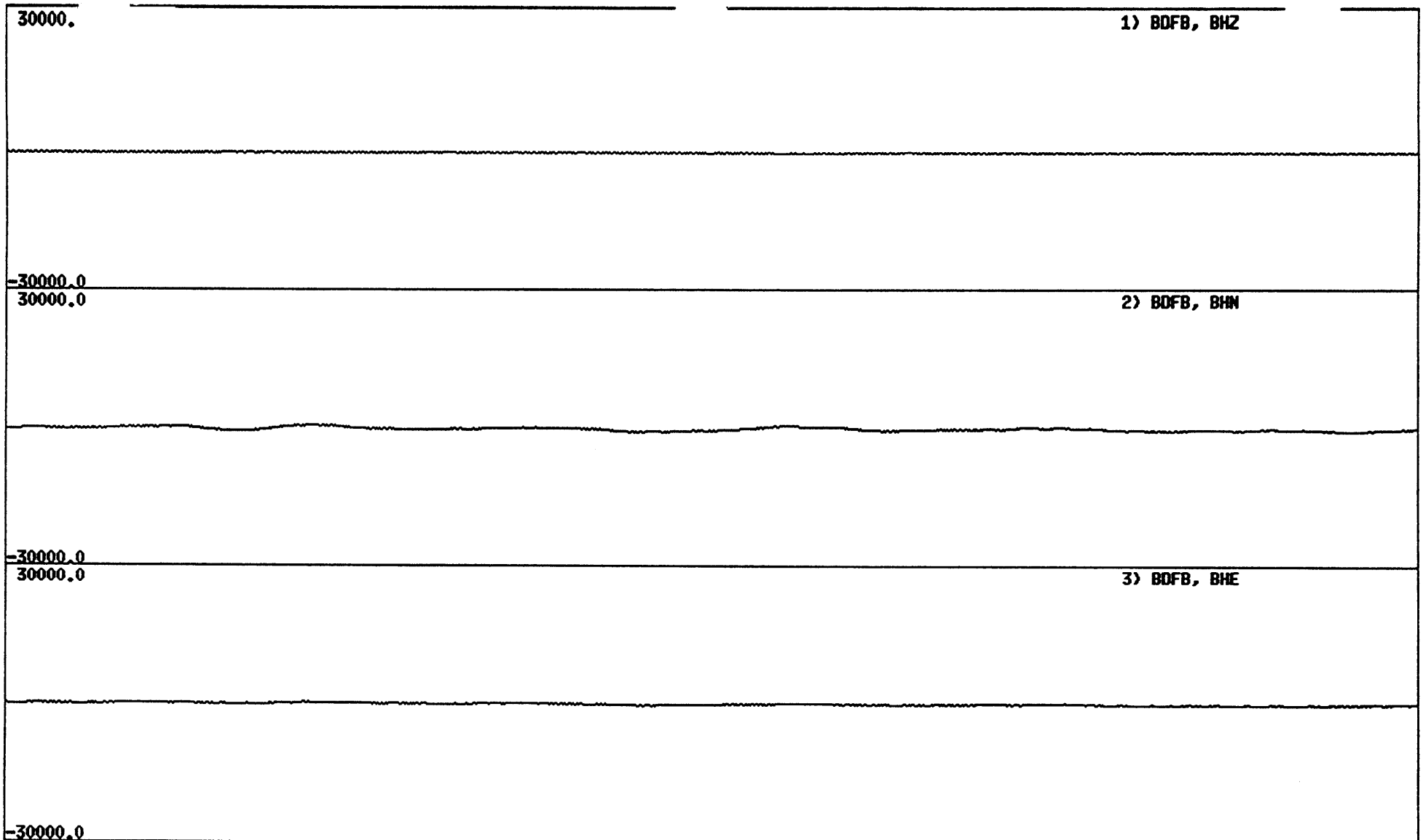
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim



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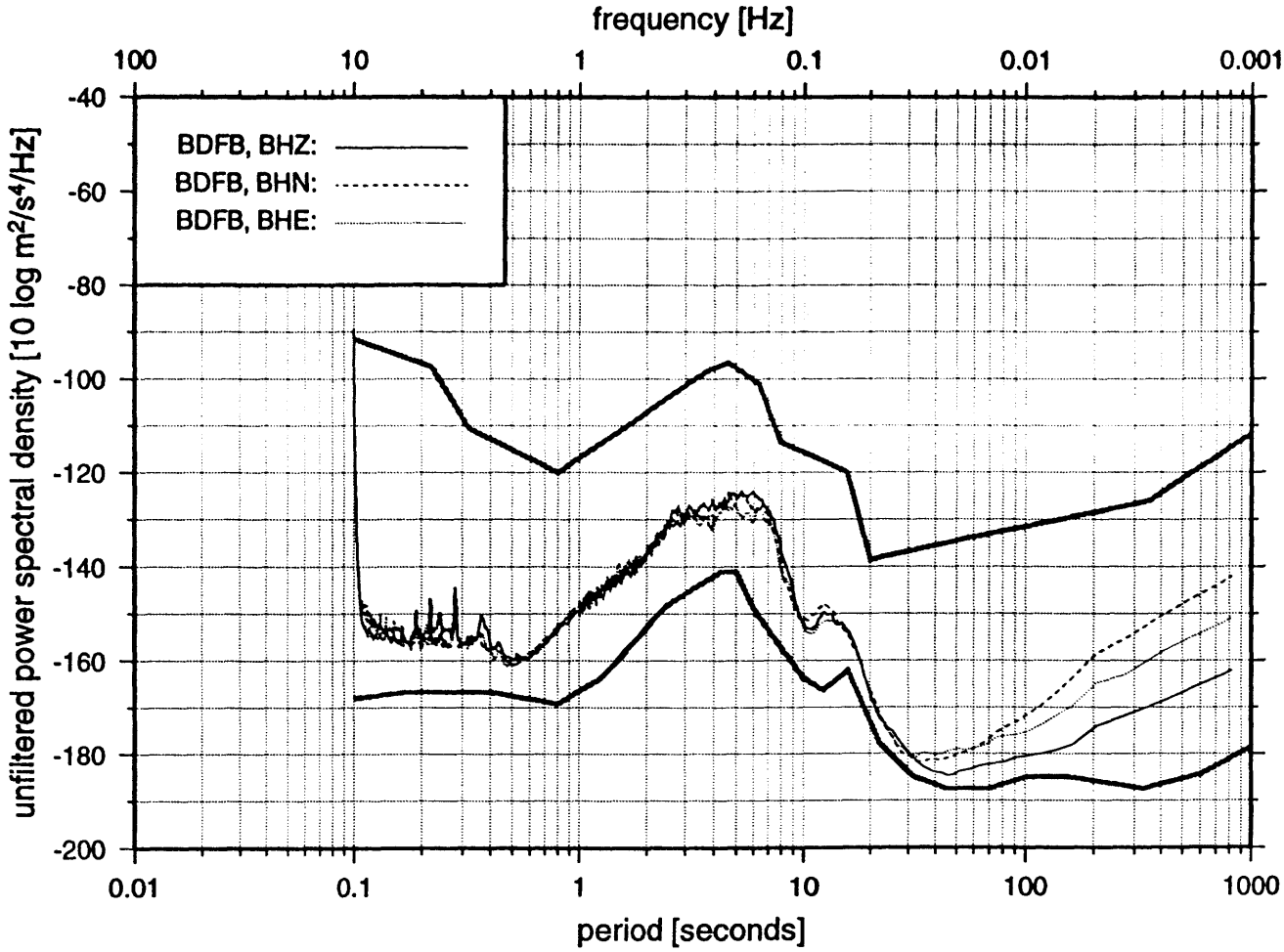
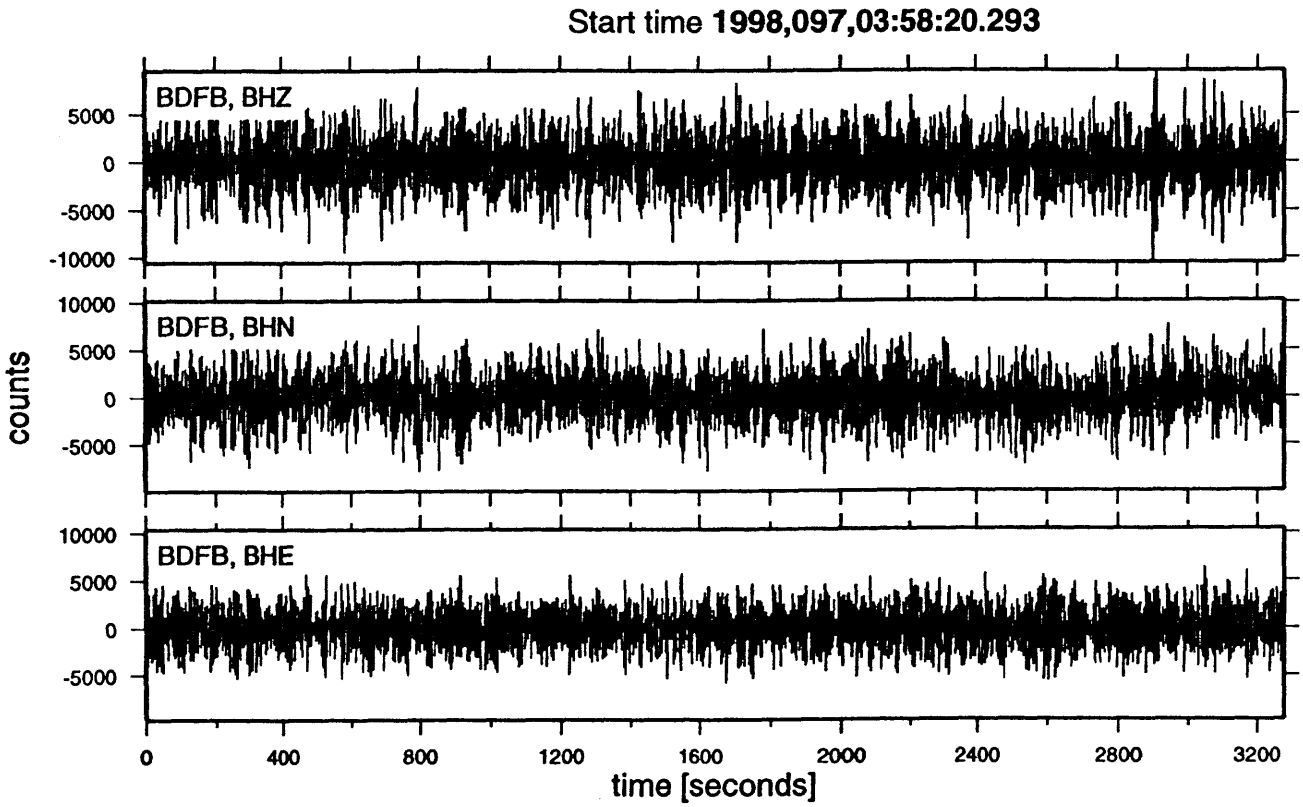
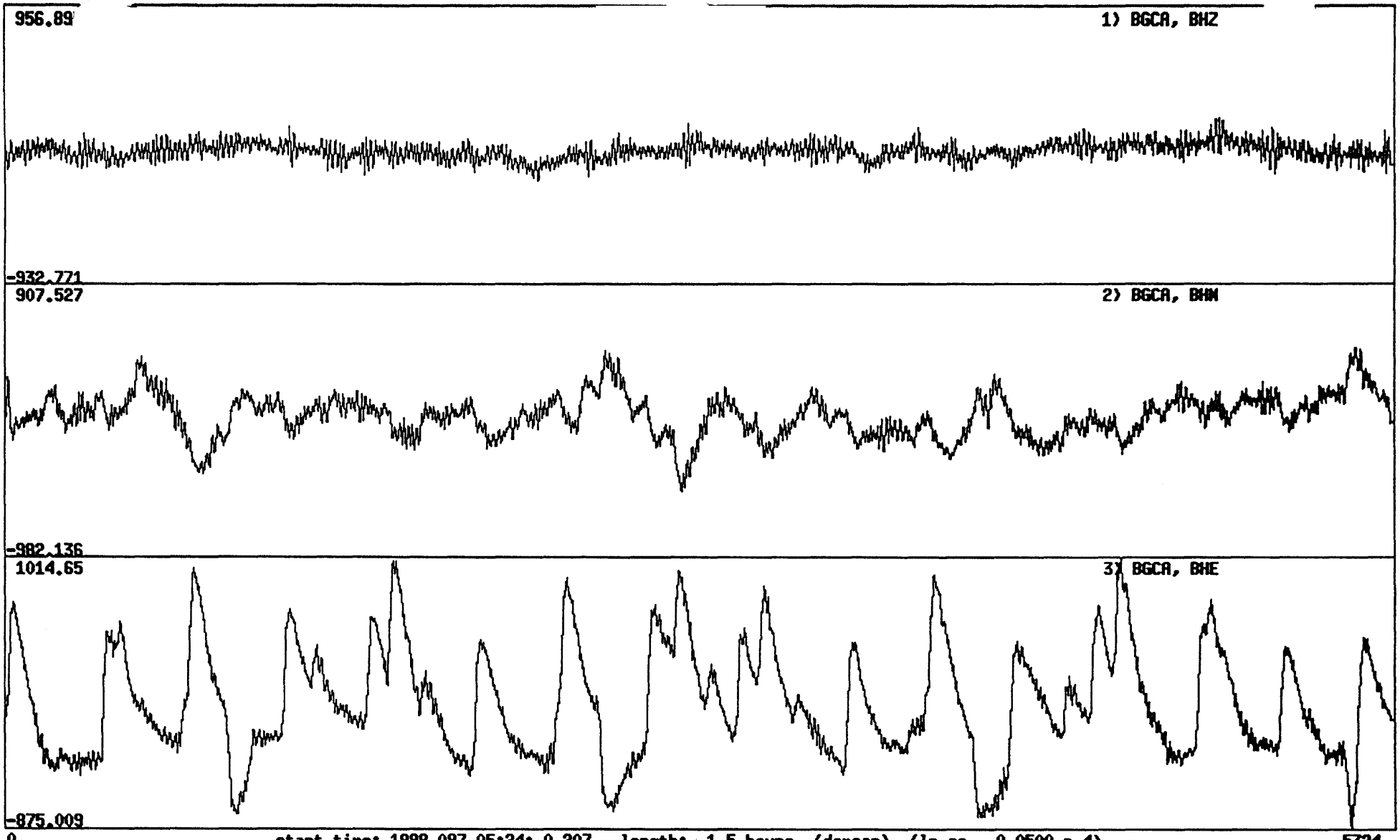
Seismic Spectra and Waveform Plot







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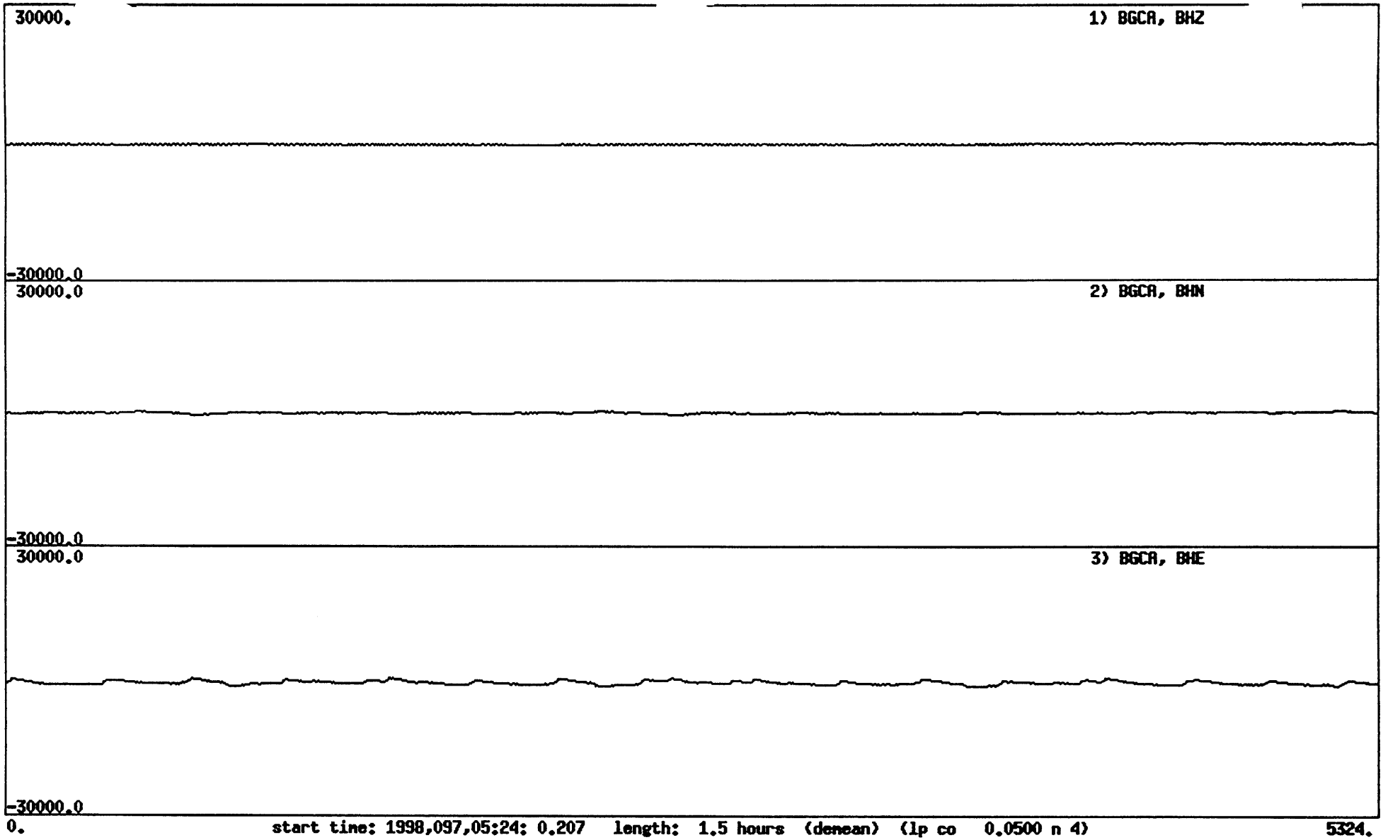

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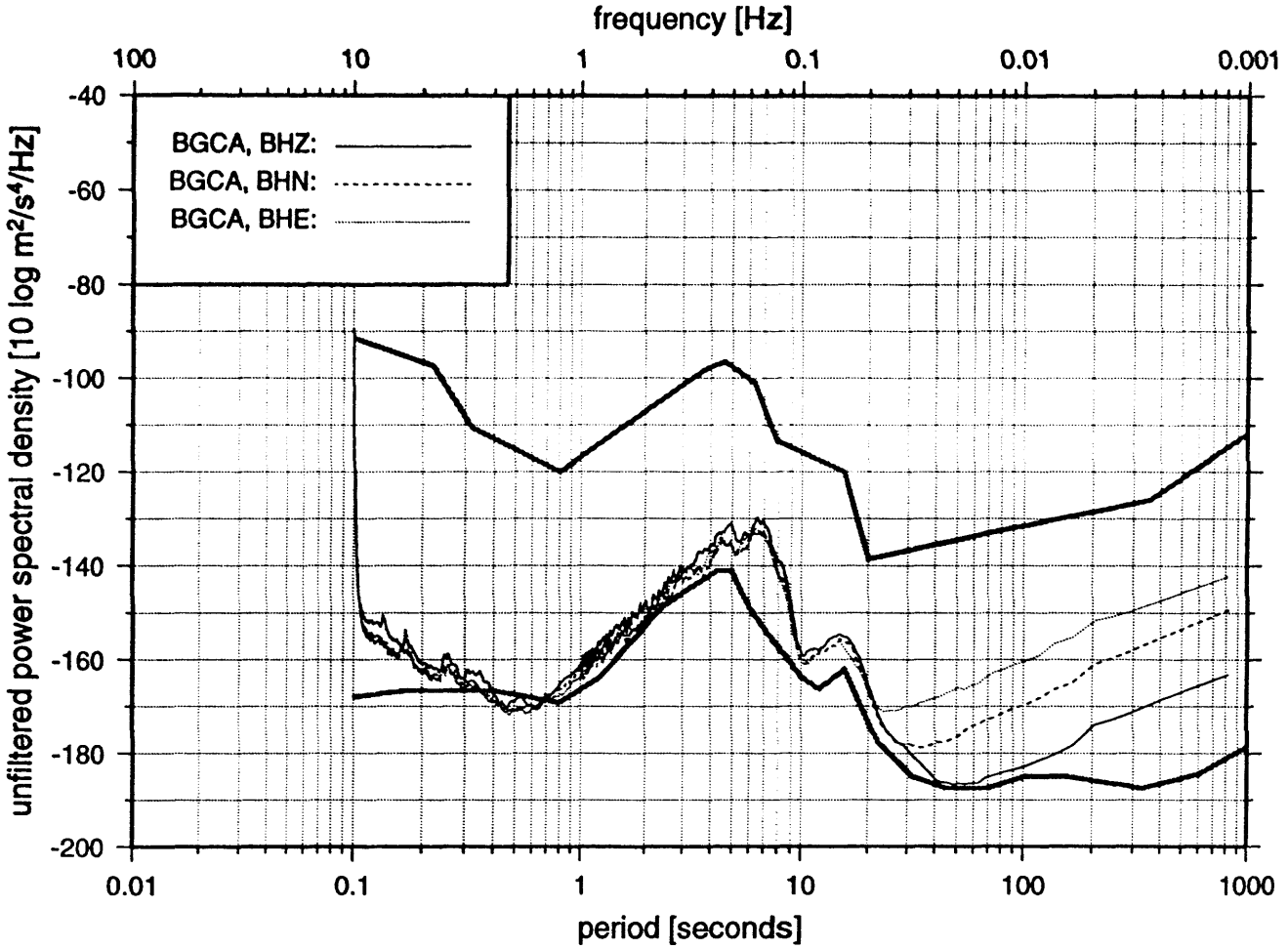
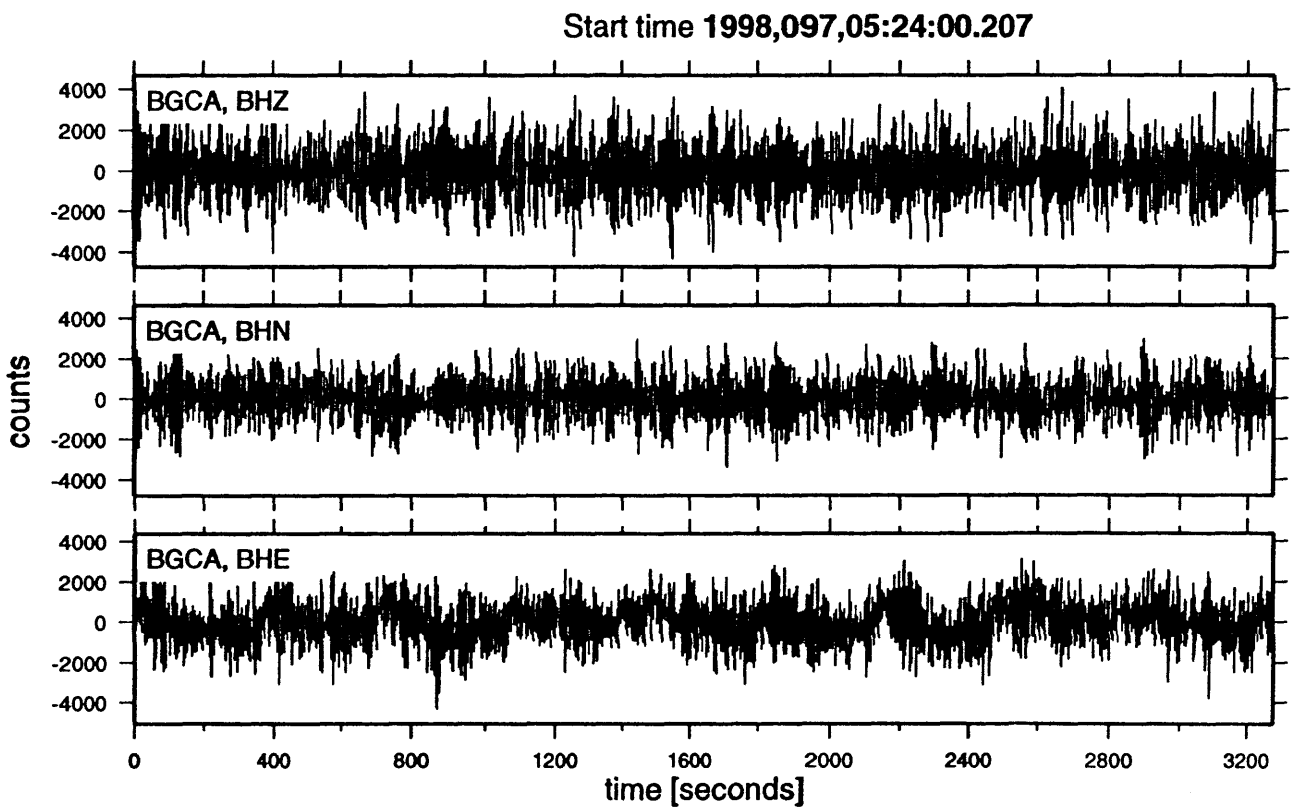
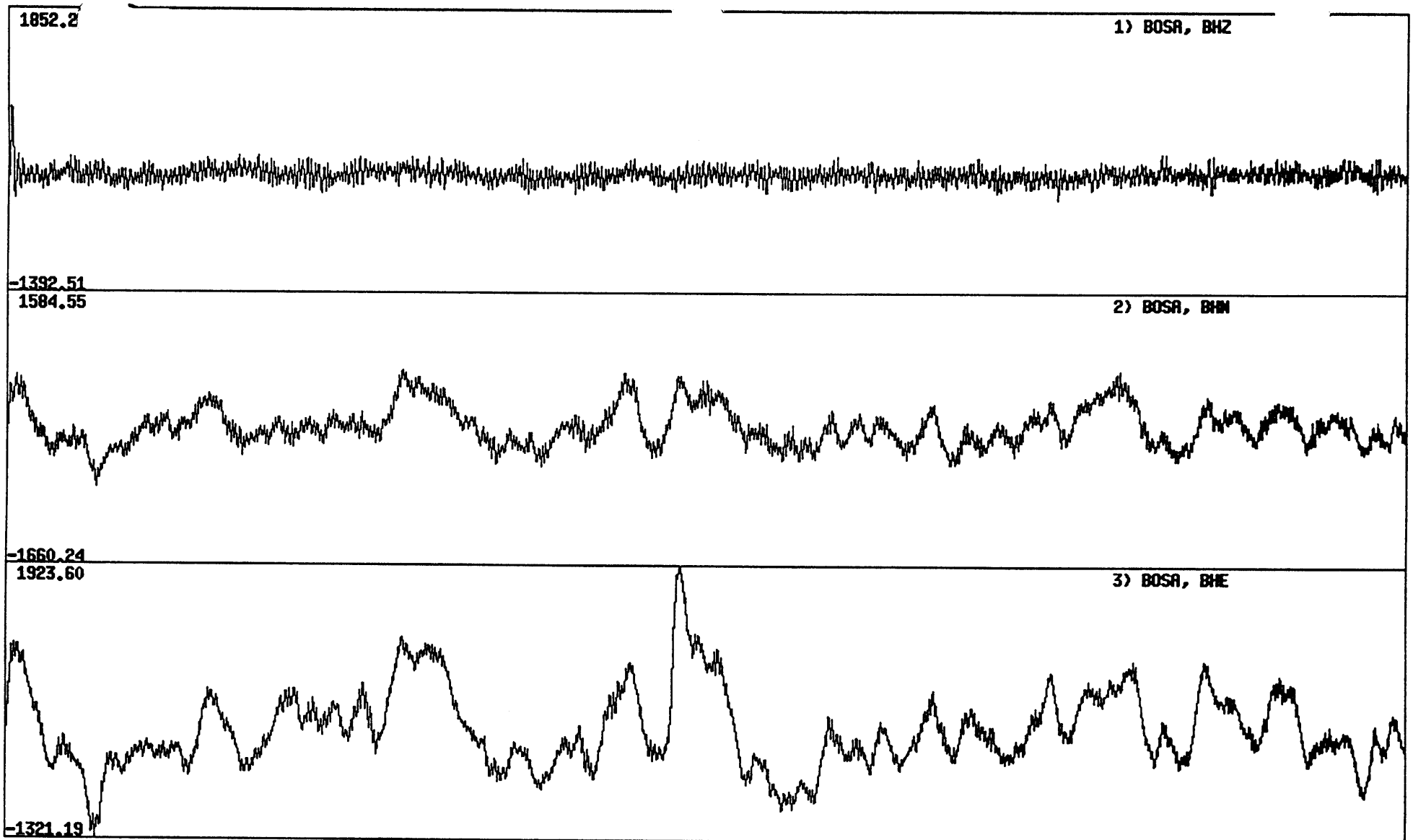
Seismic Spectra and Waveform Plot







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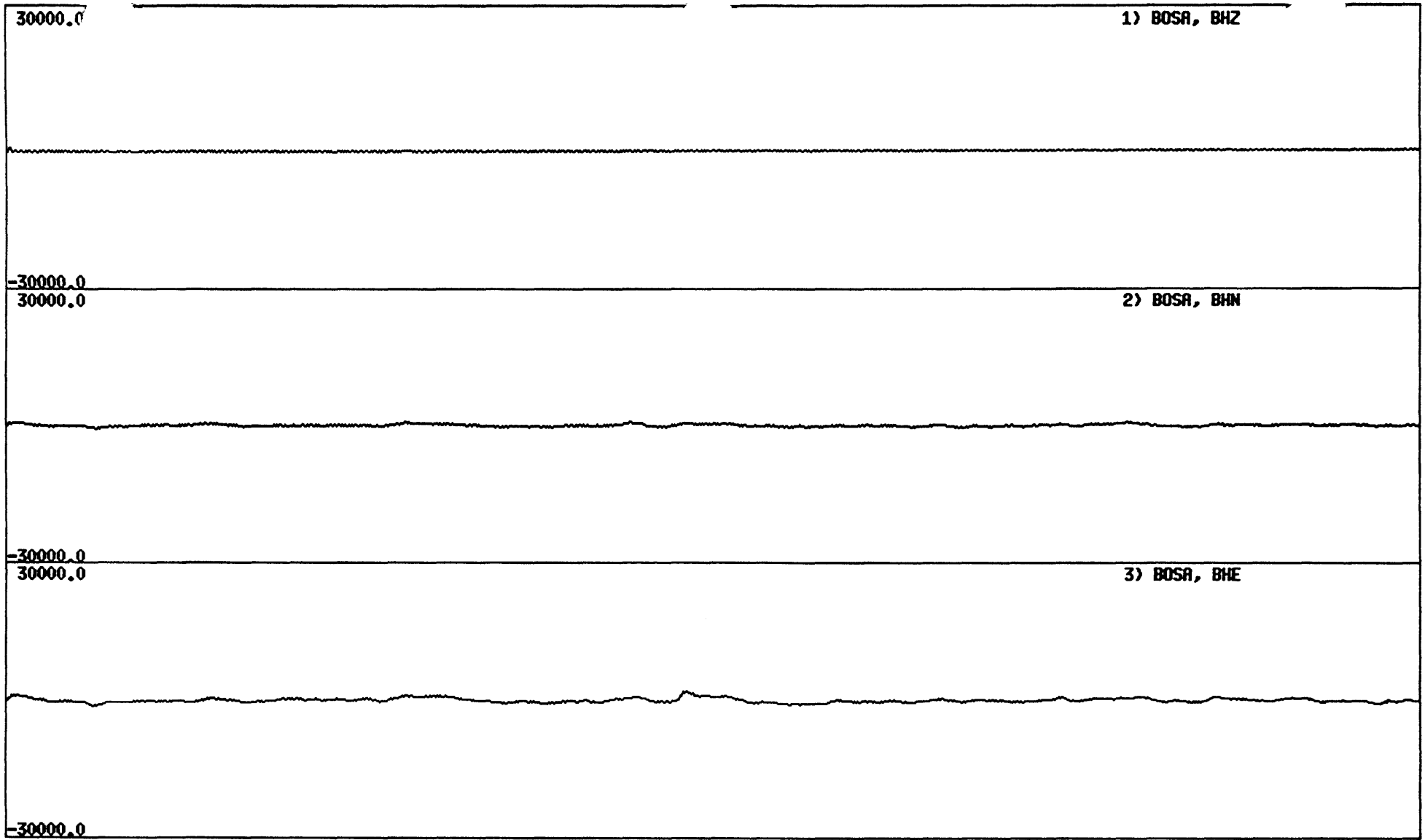

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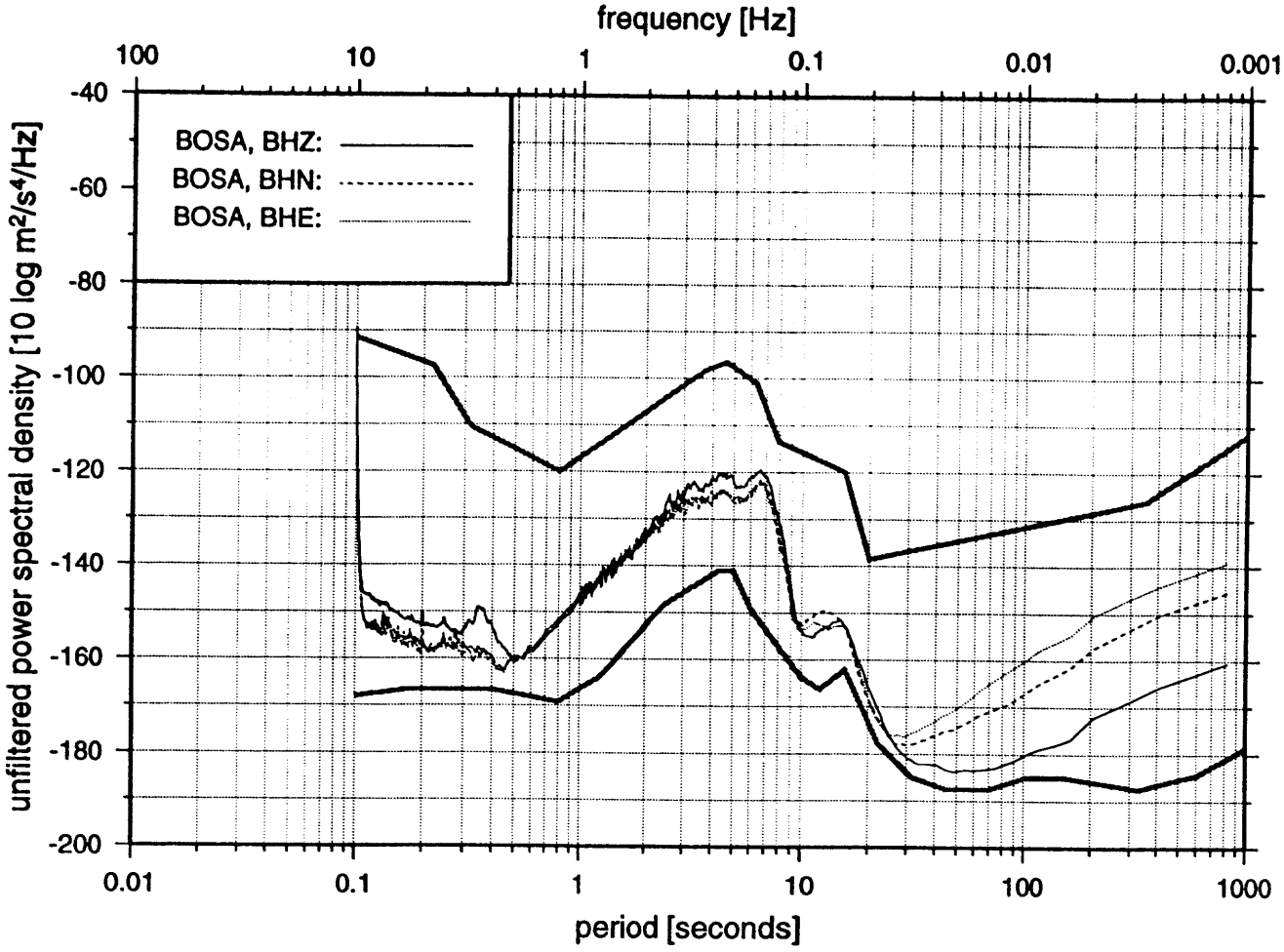
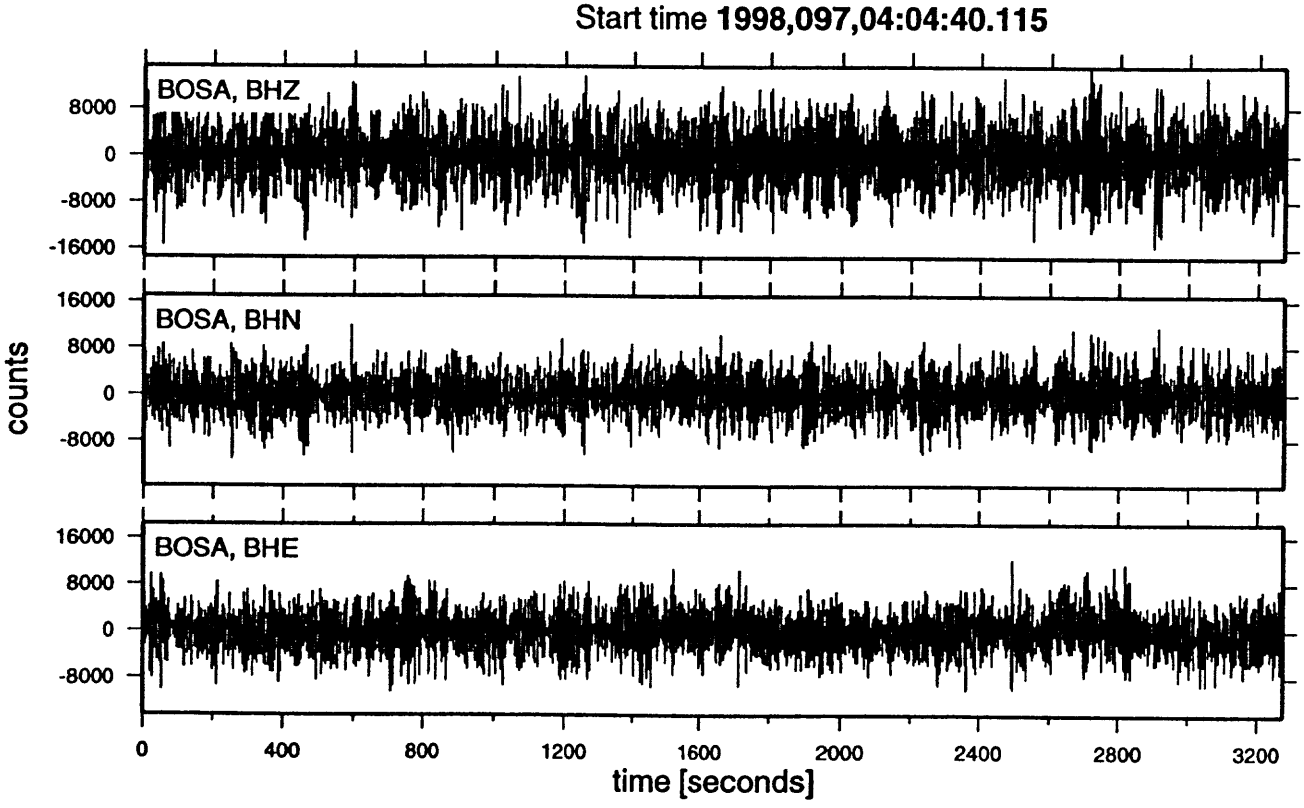
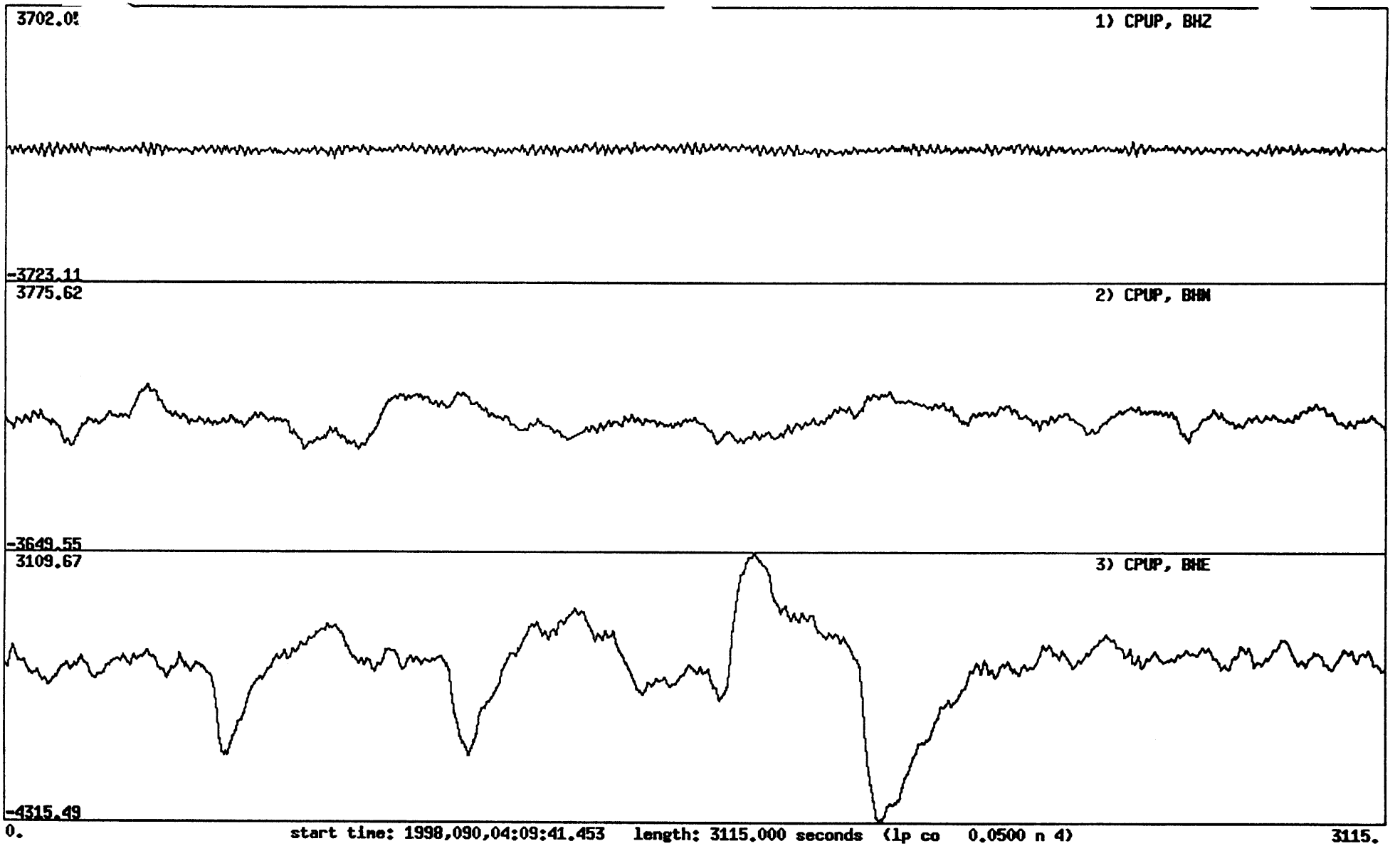
Seismic Spectra and Waveform Plot







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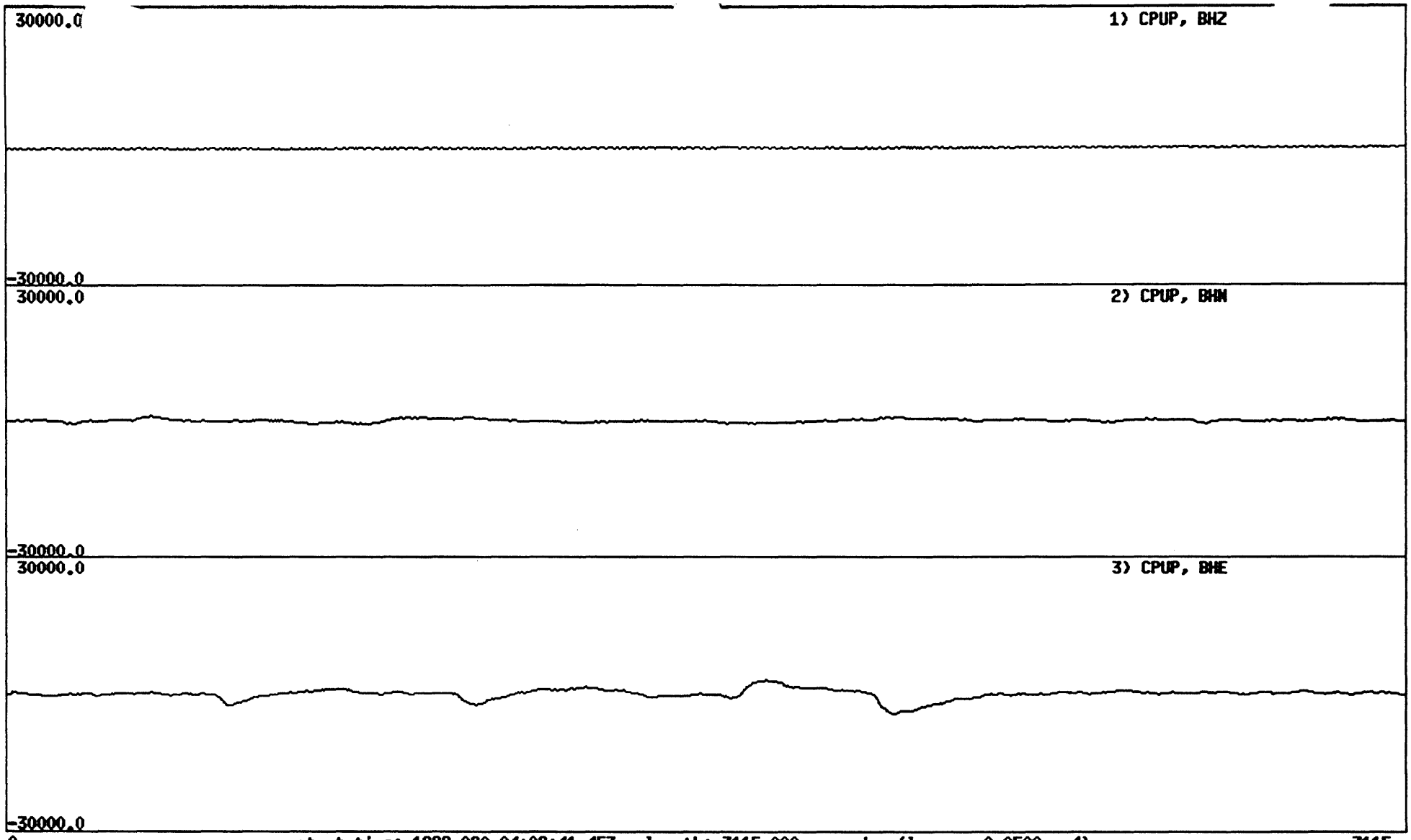

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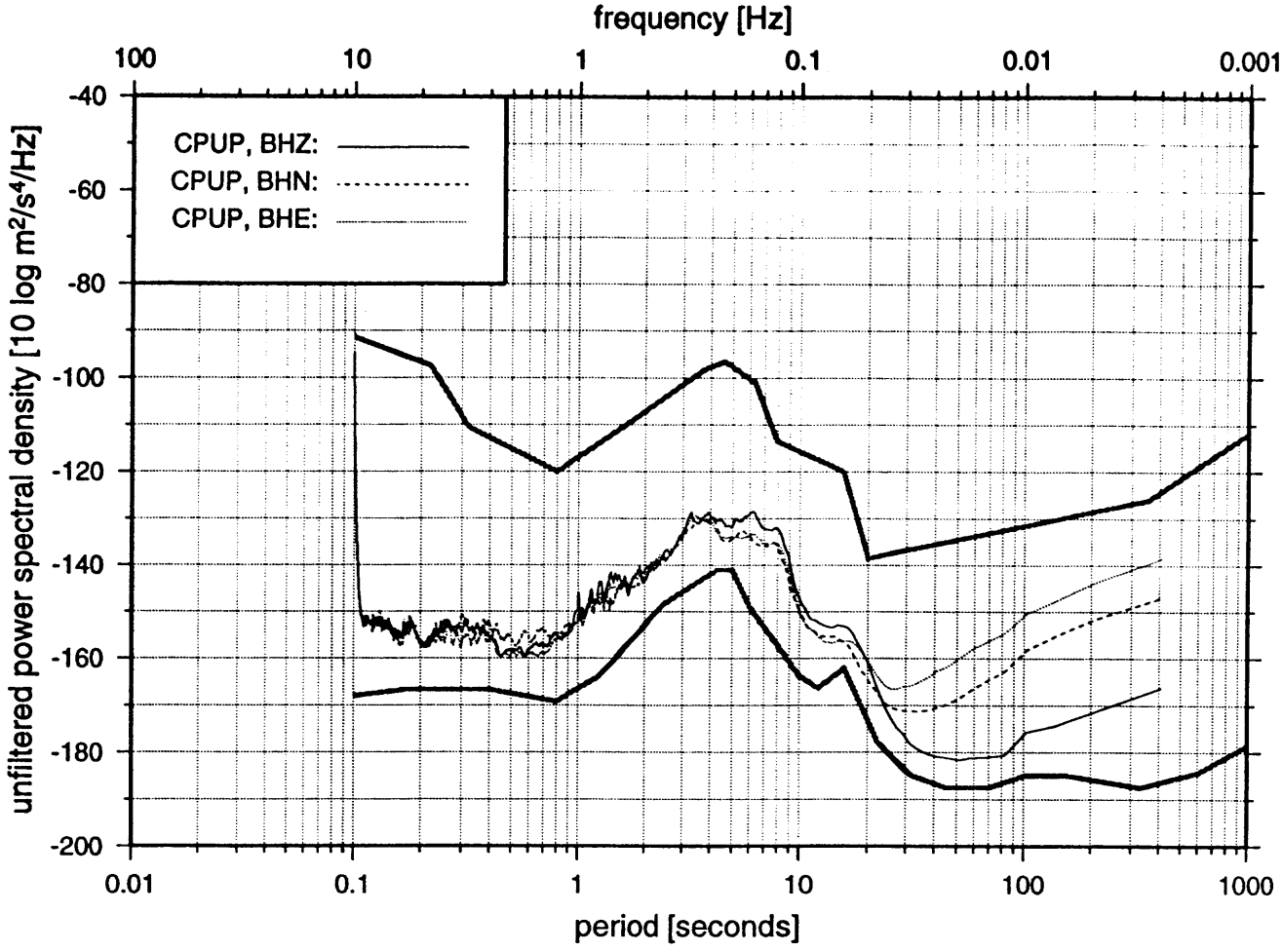
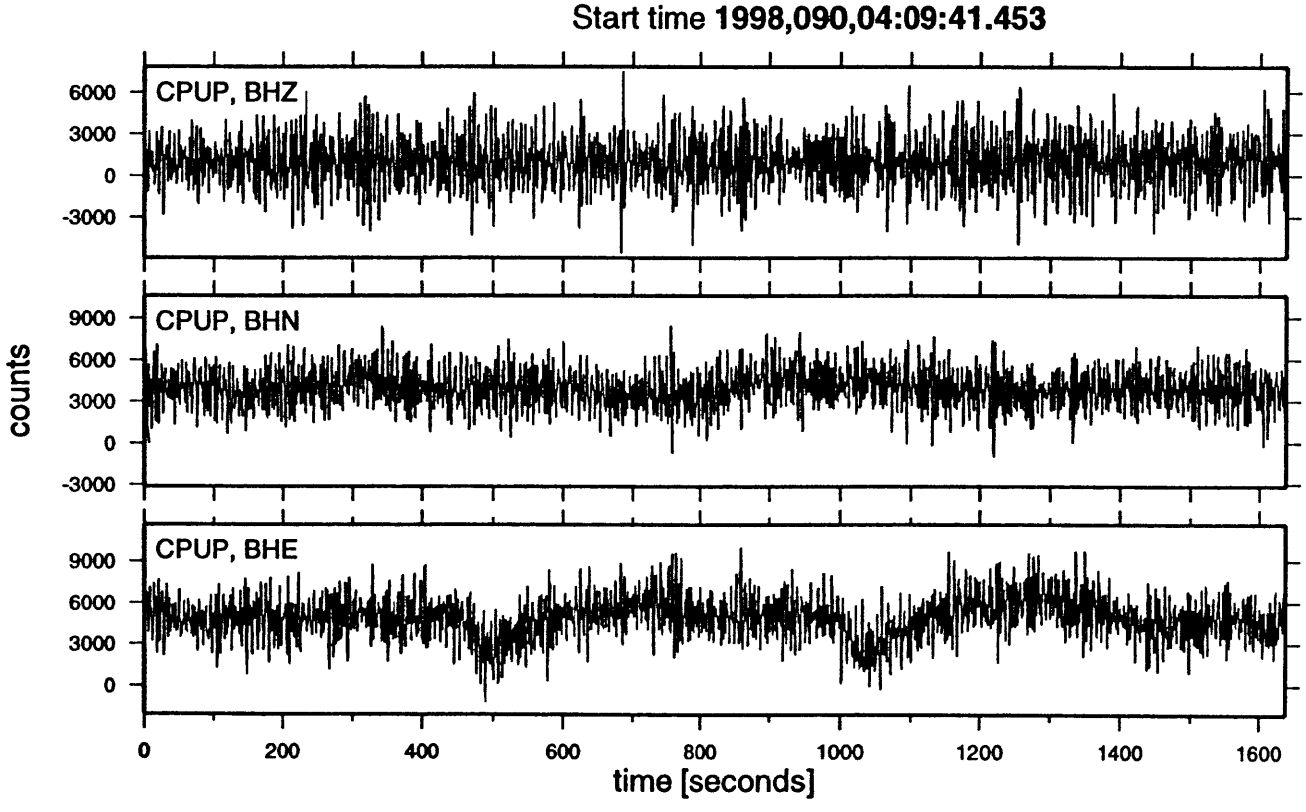
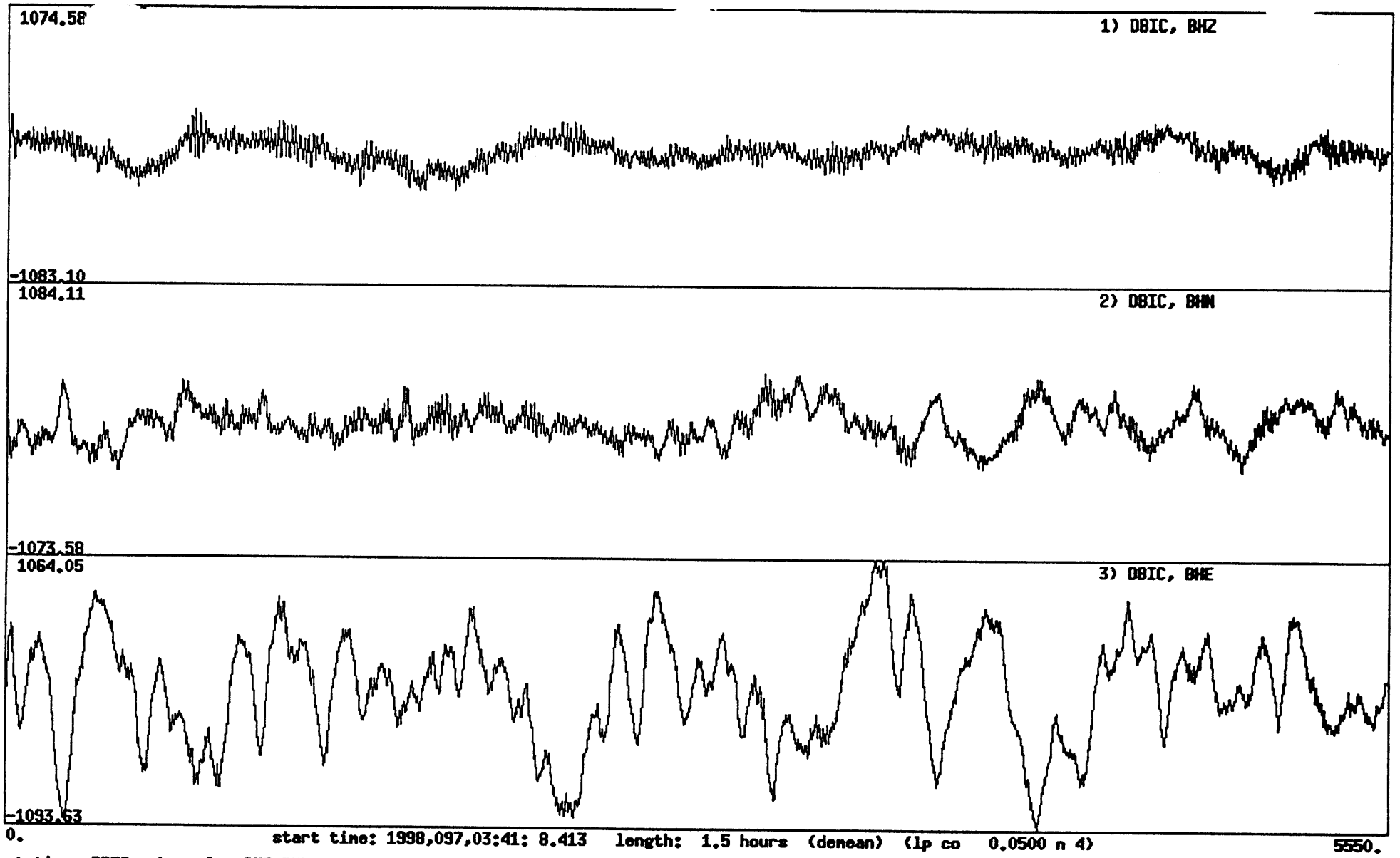
Seismic Spectra and Waveform Plot







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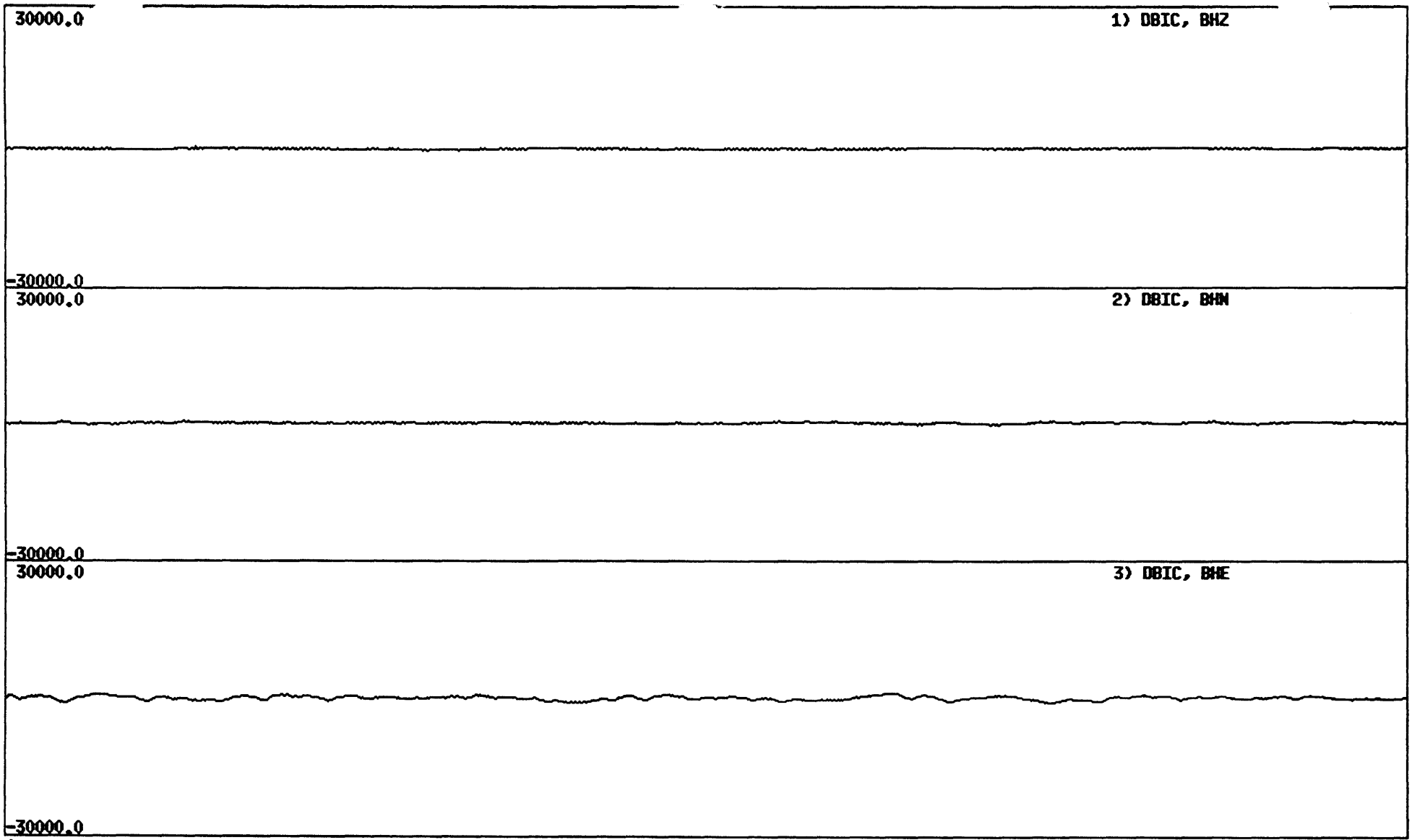

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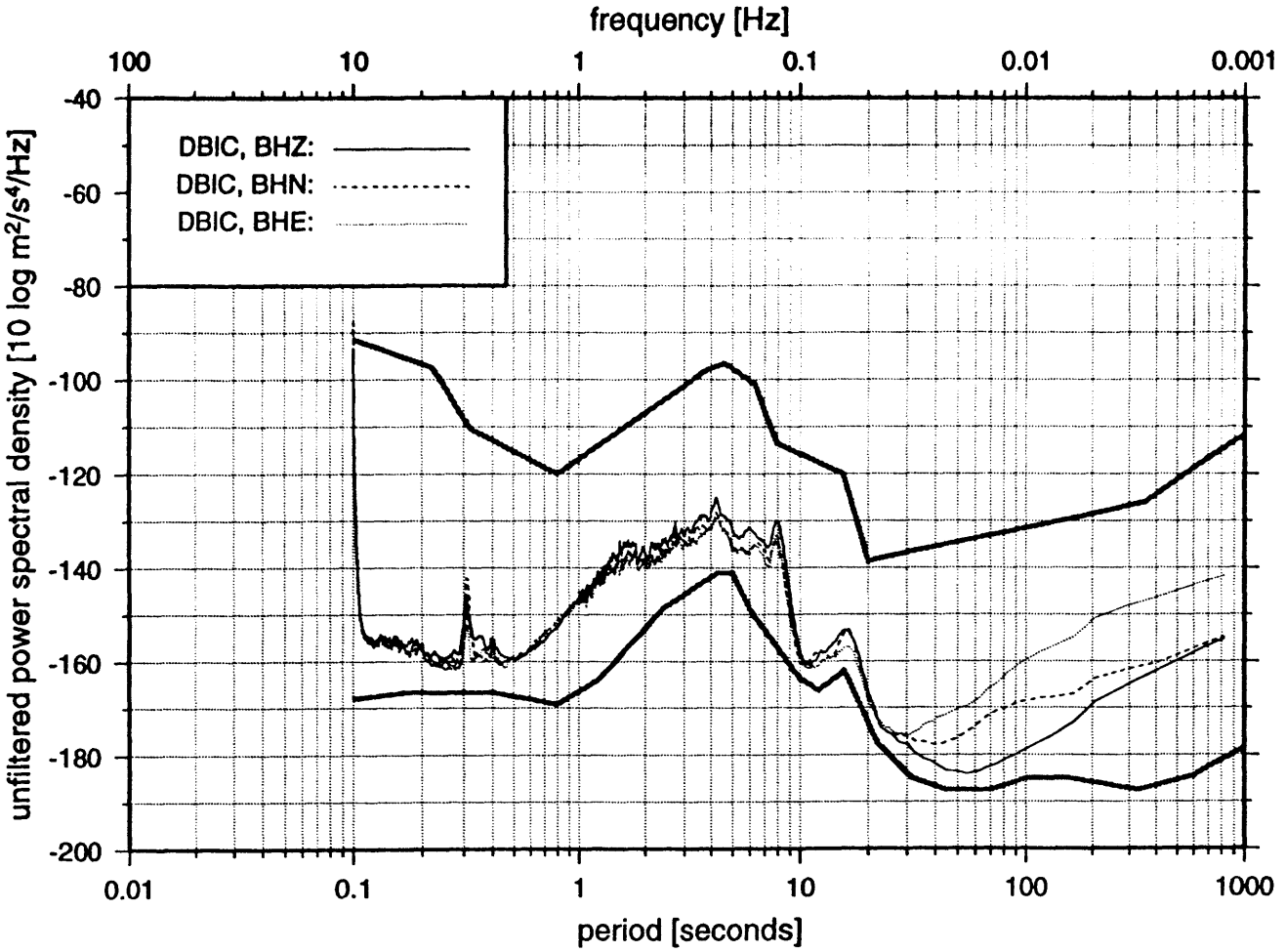
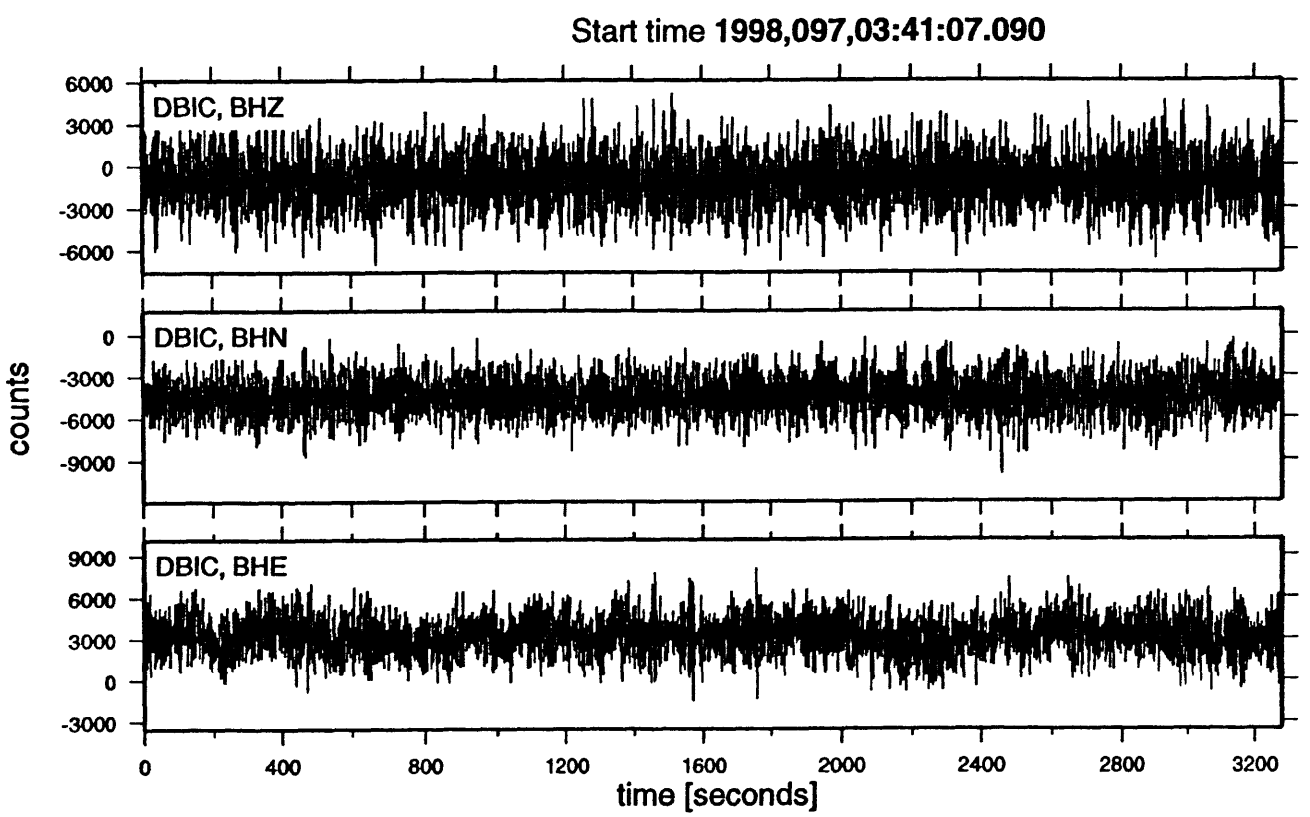
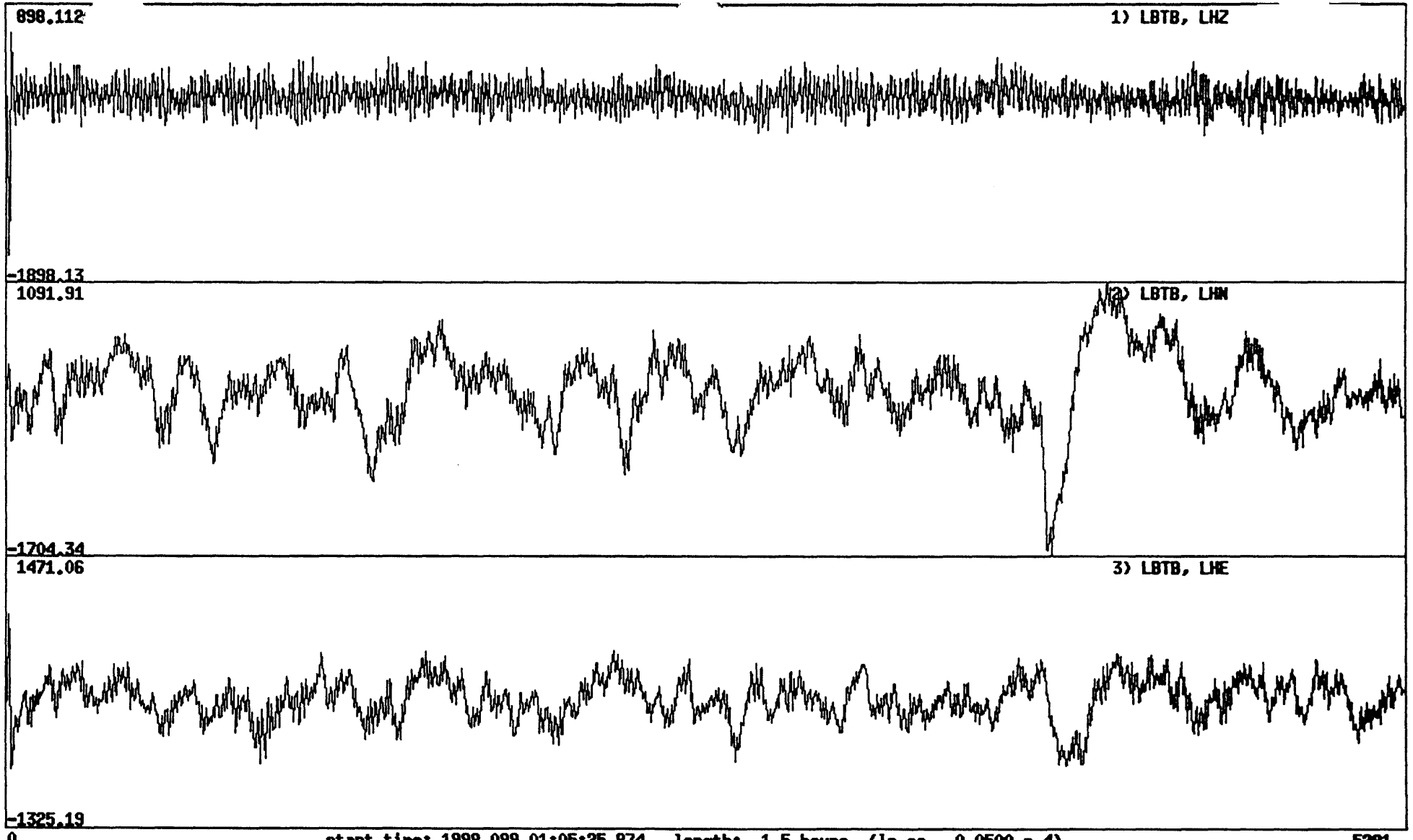
Seismic Spectra and Waveform Plot







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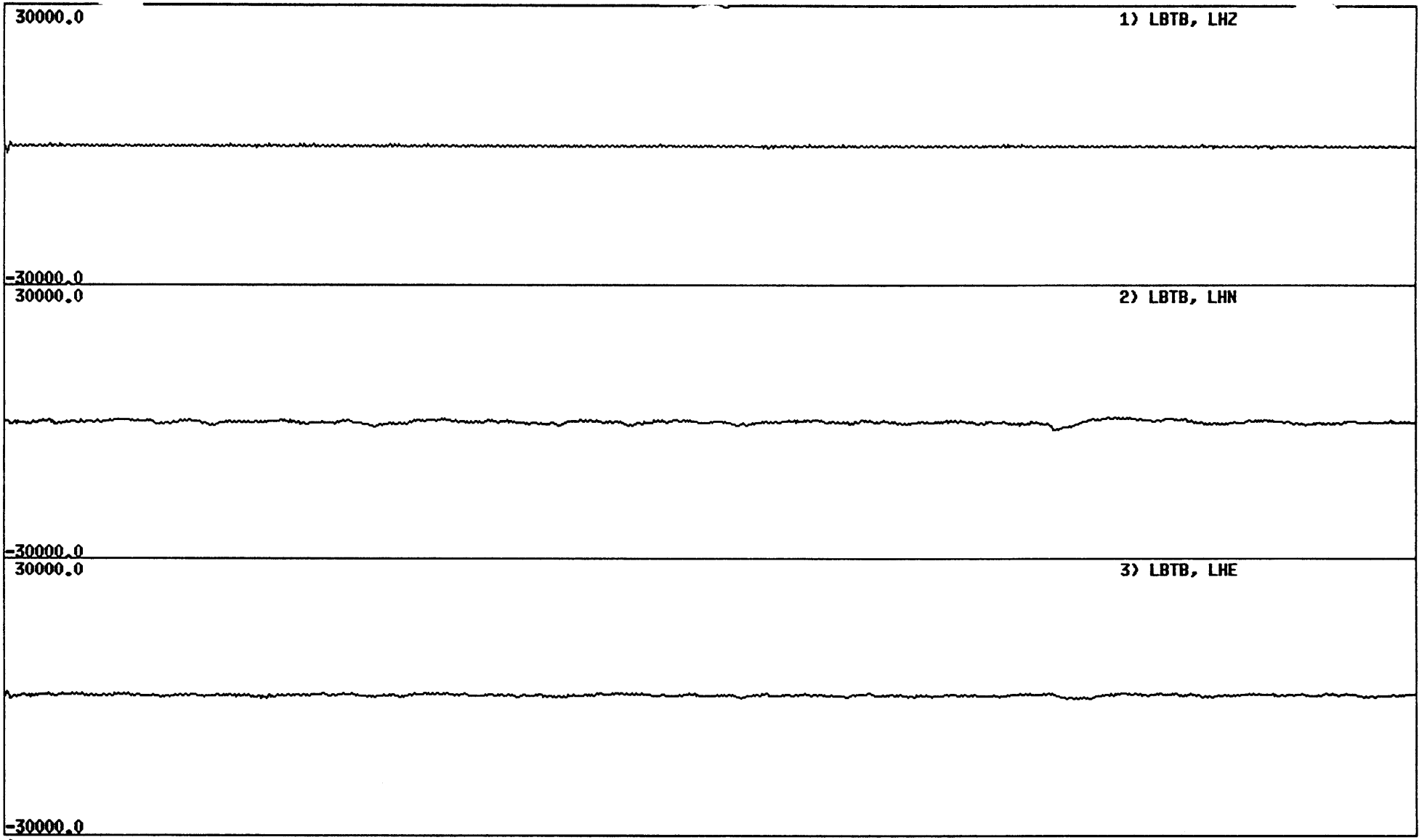

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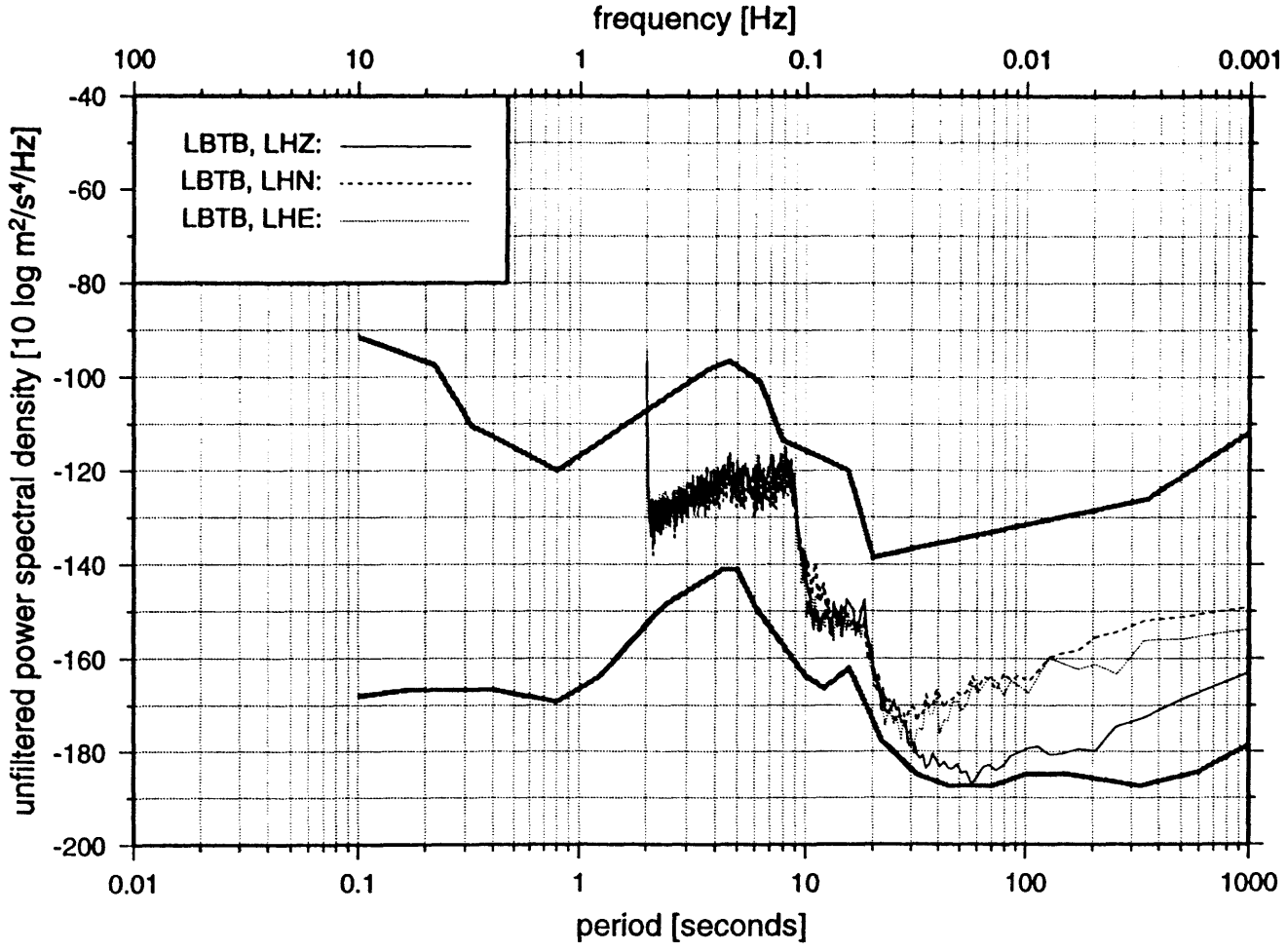
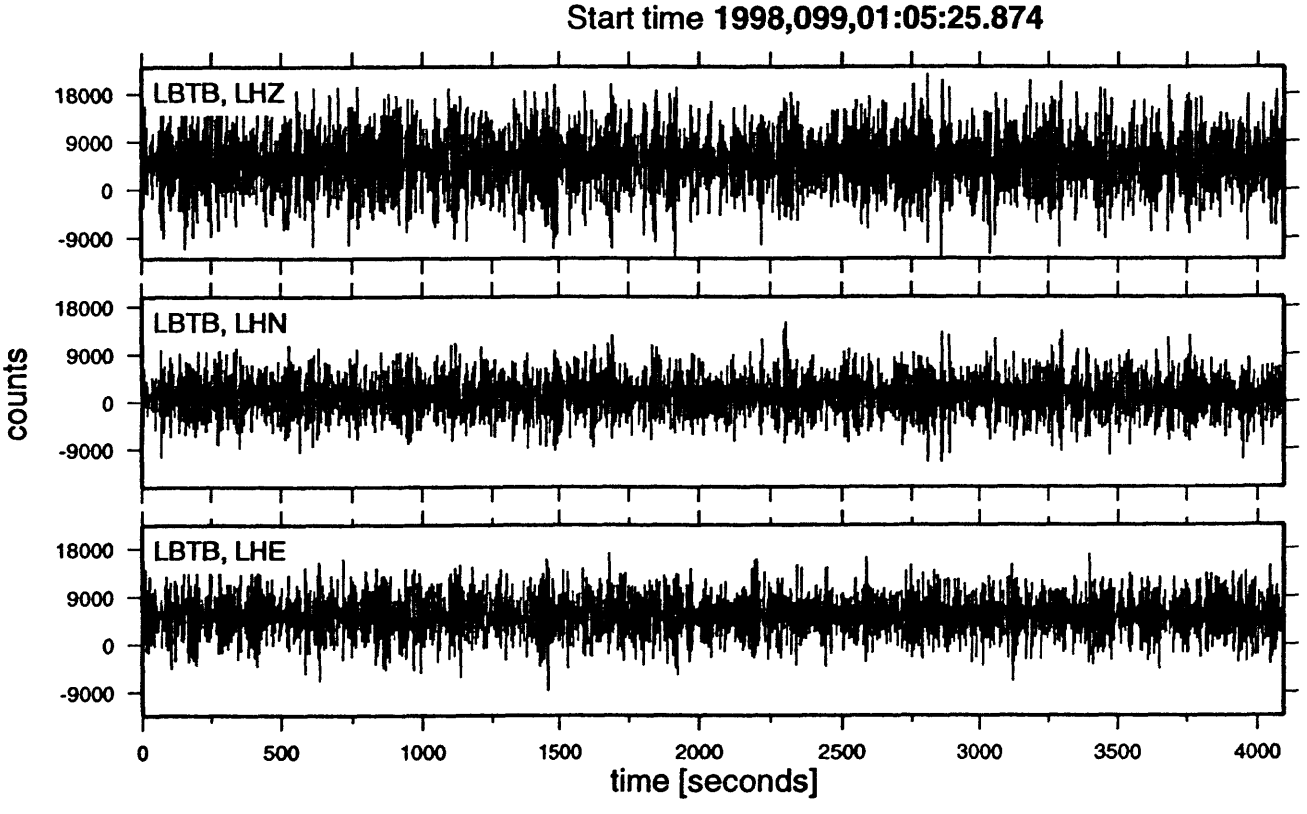
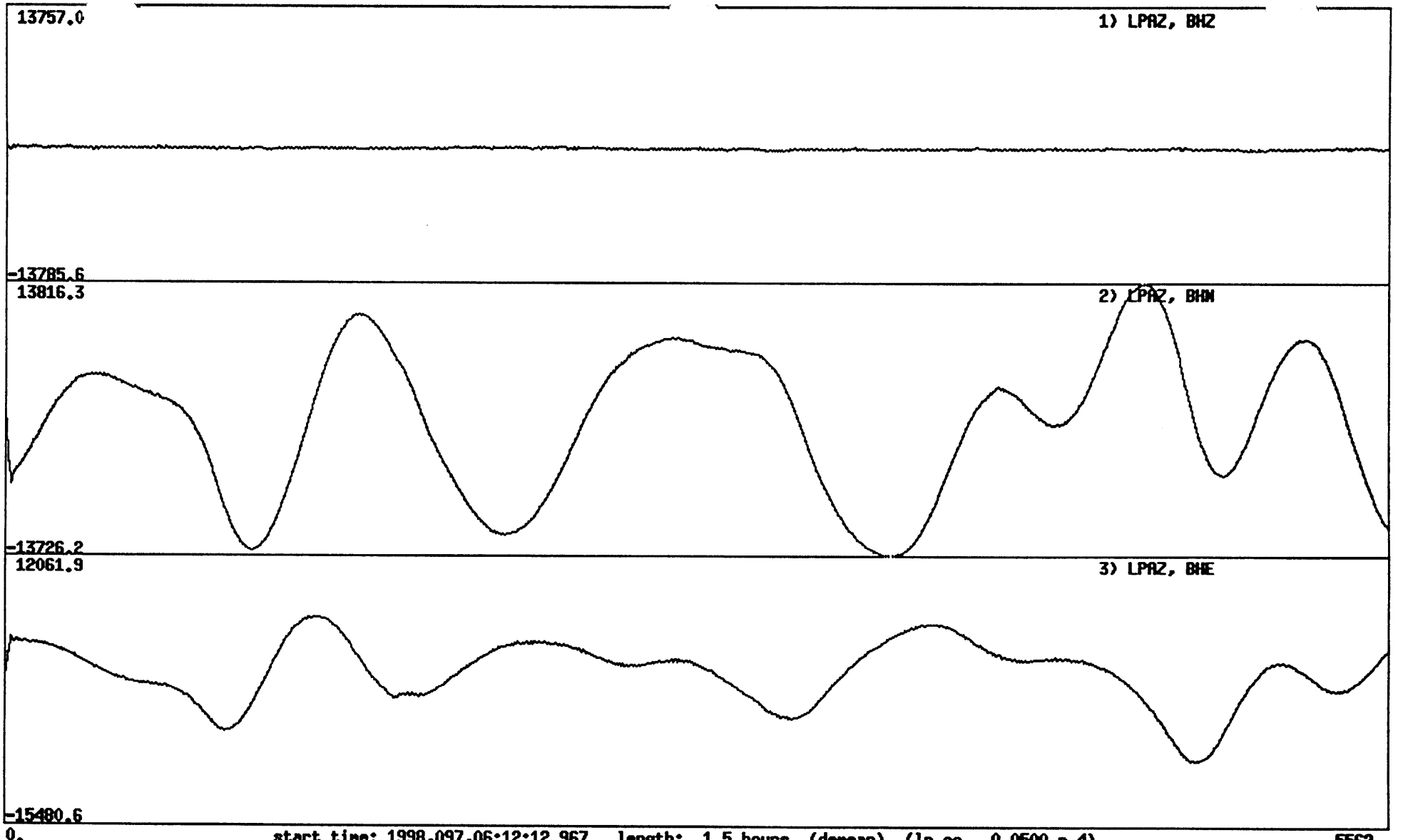
Seismic Spectra and Waveform Plot







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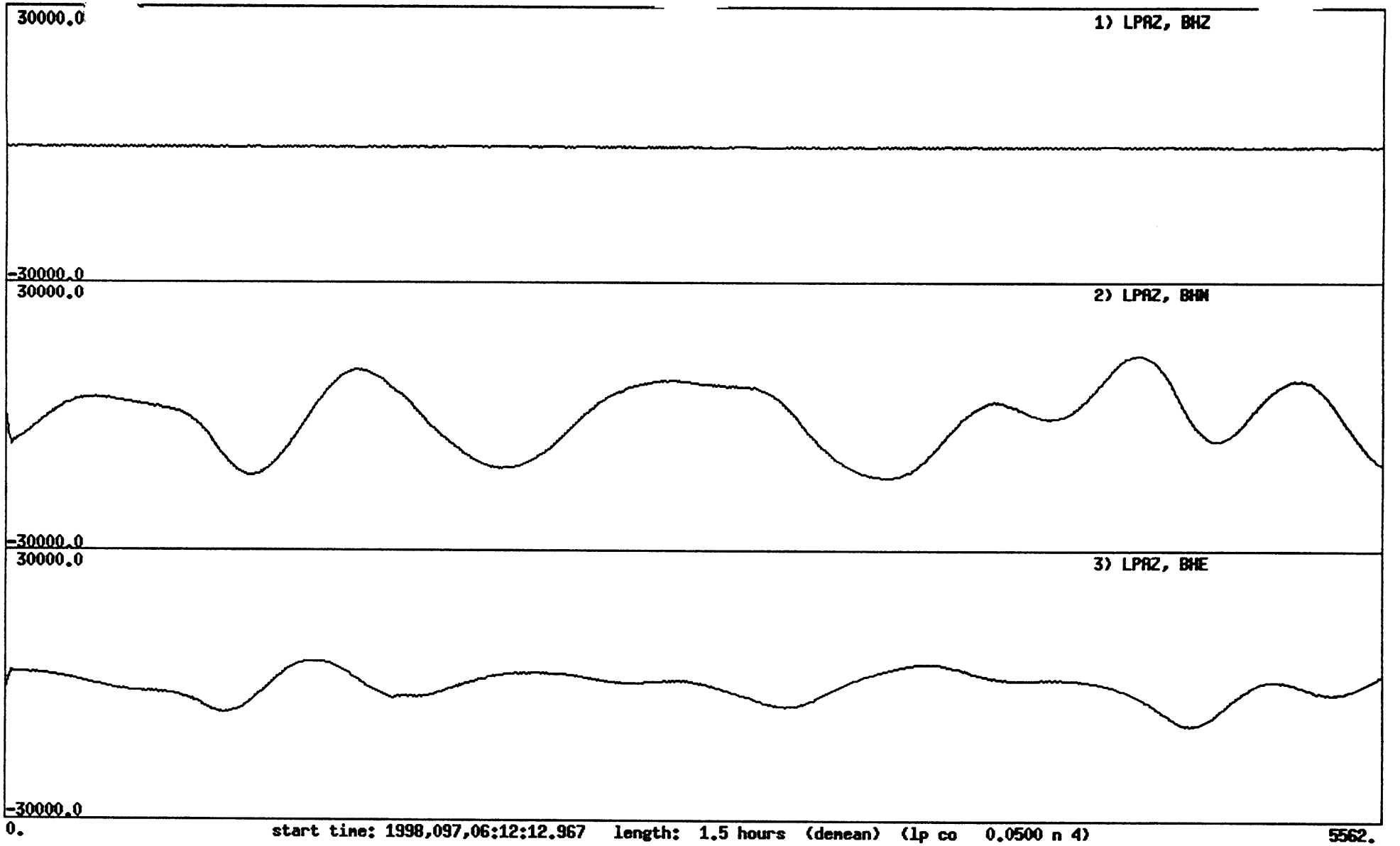

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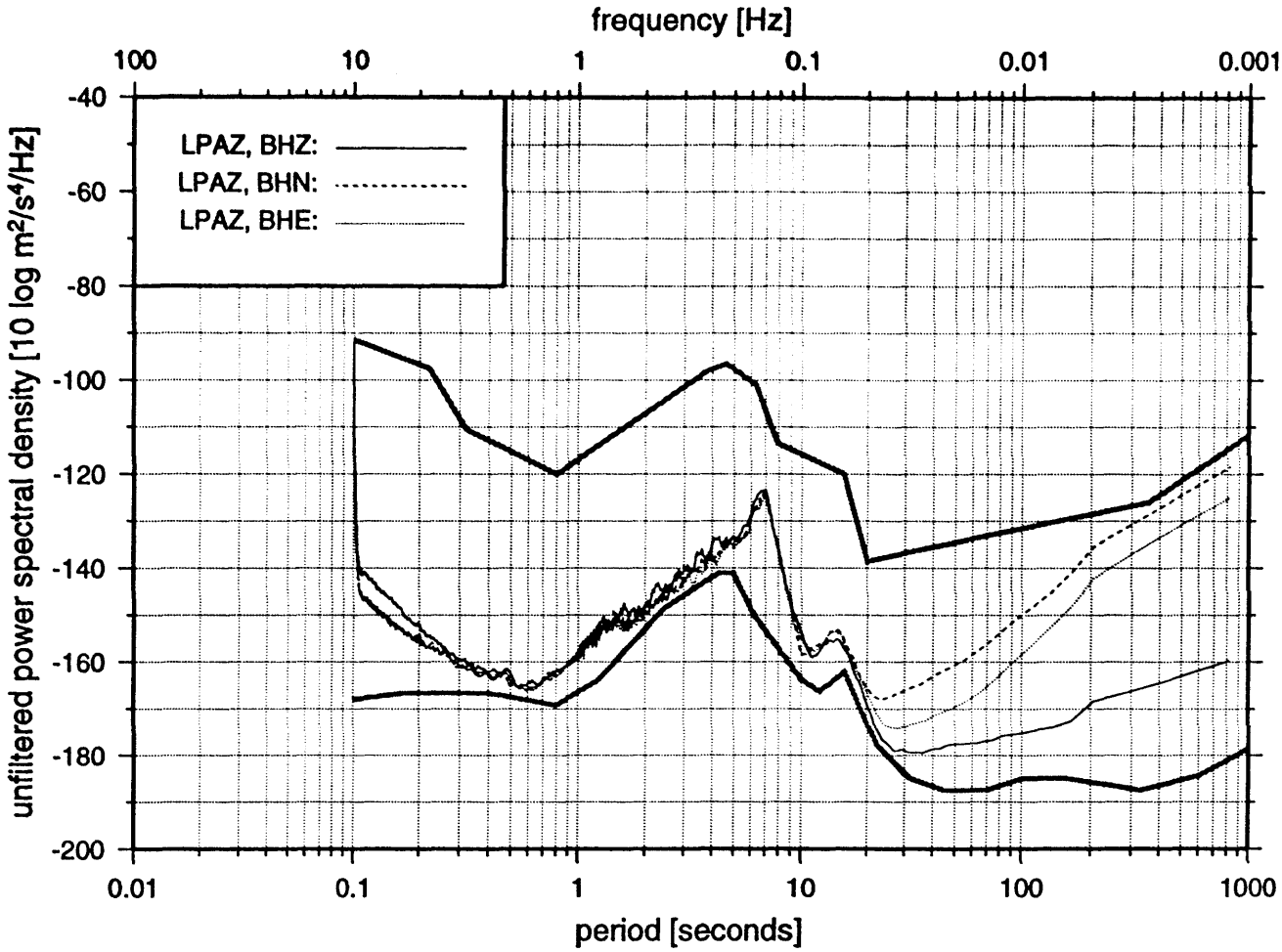
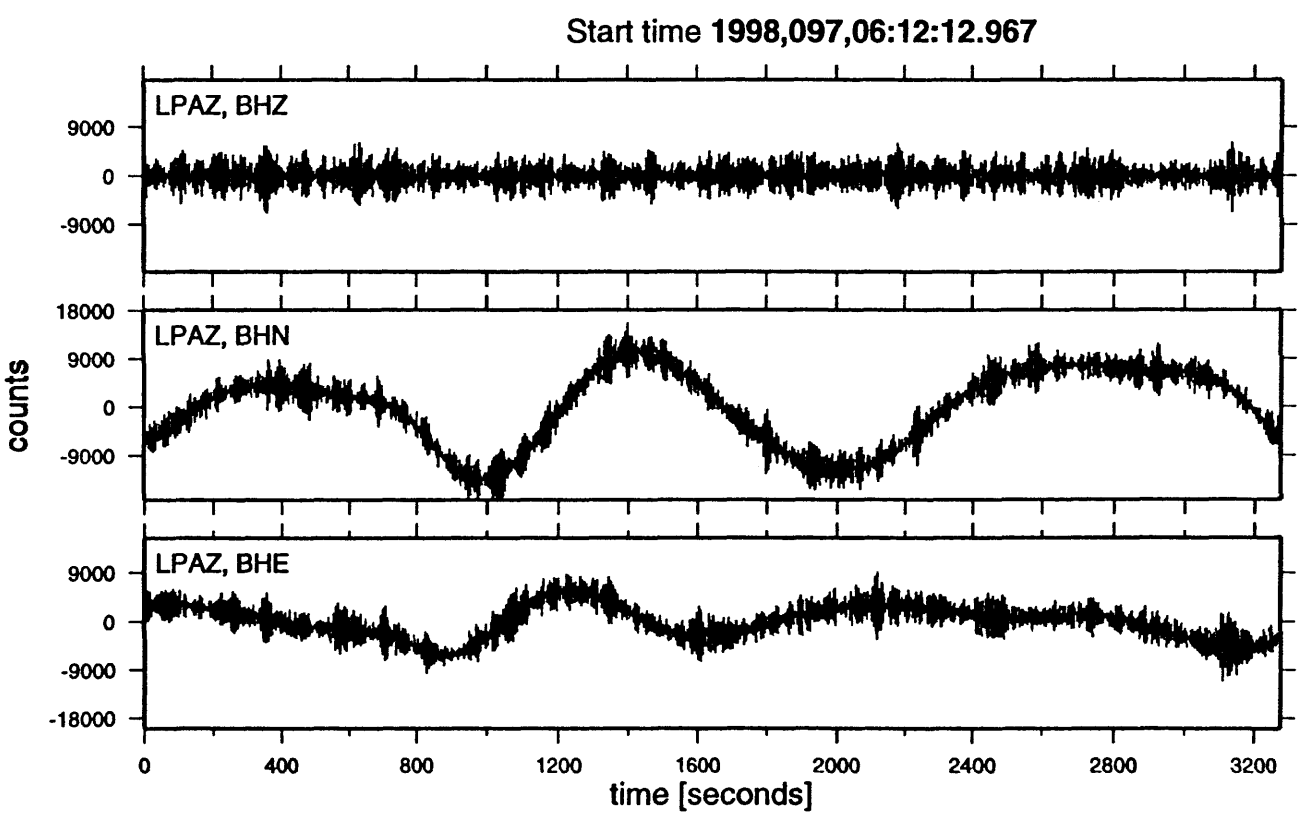
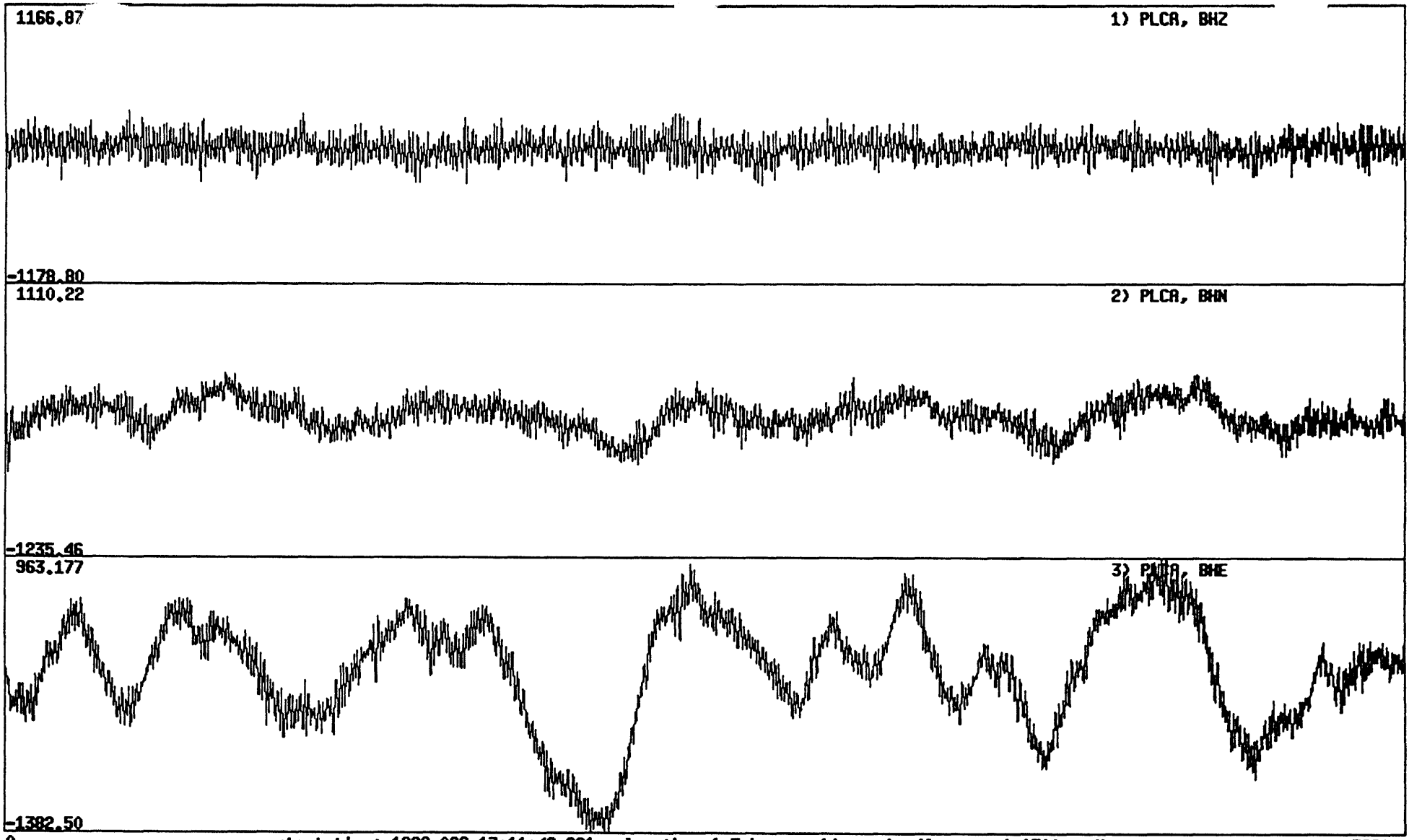
Seismic Spectra and Waveform Plot







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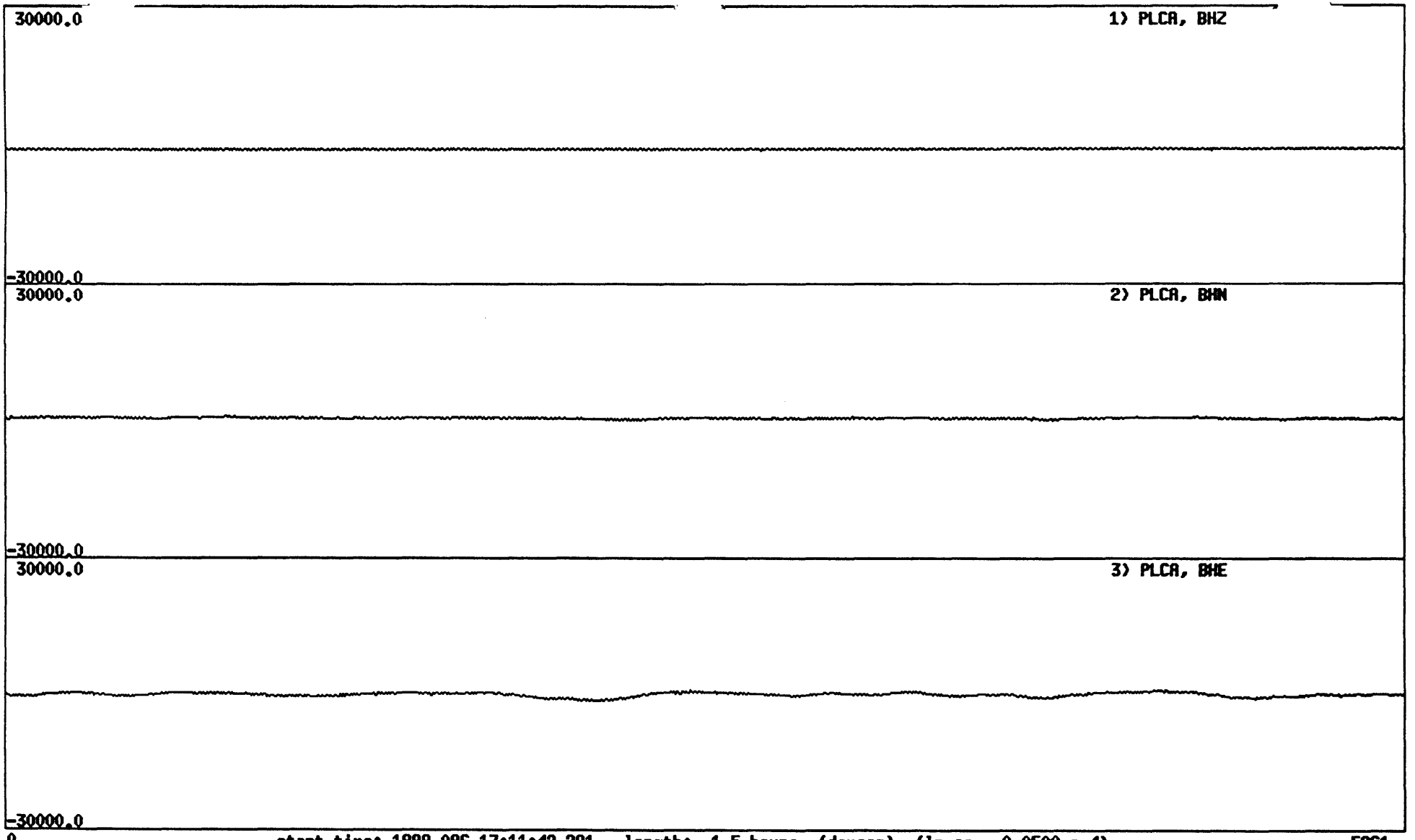
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

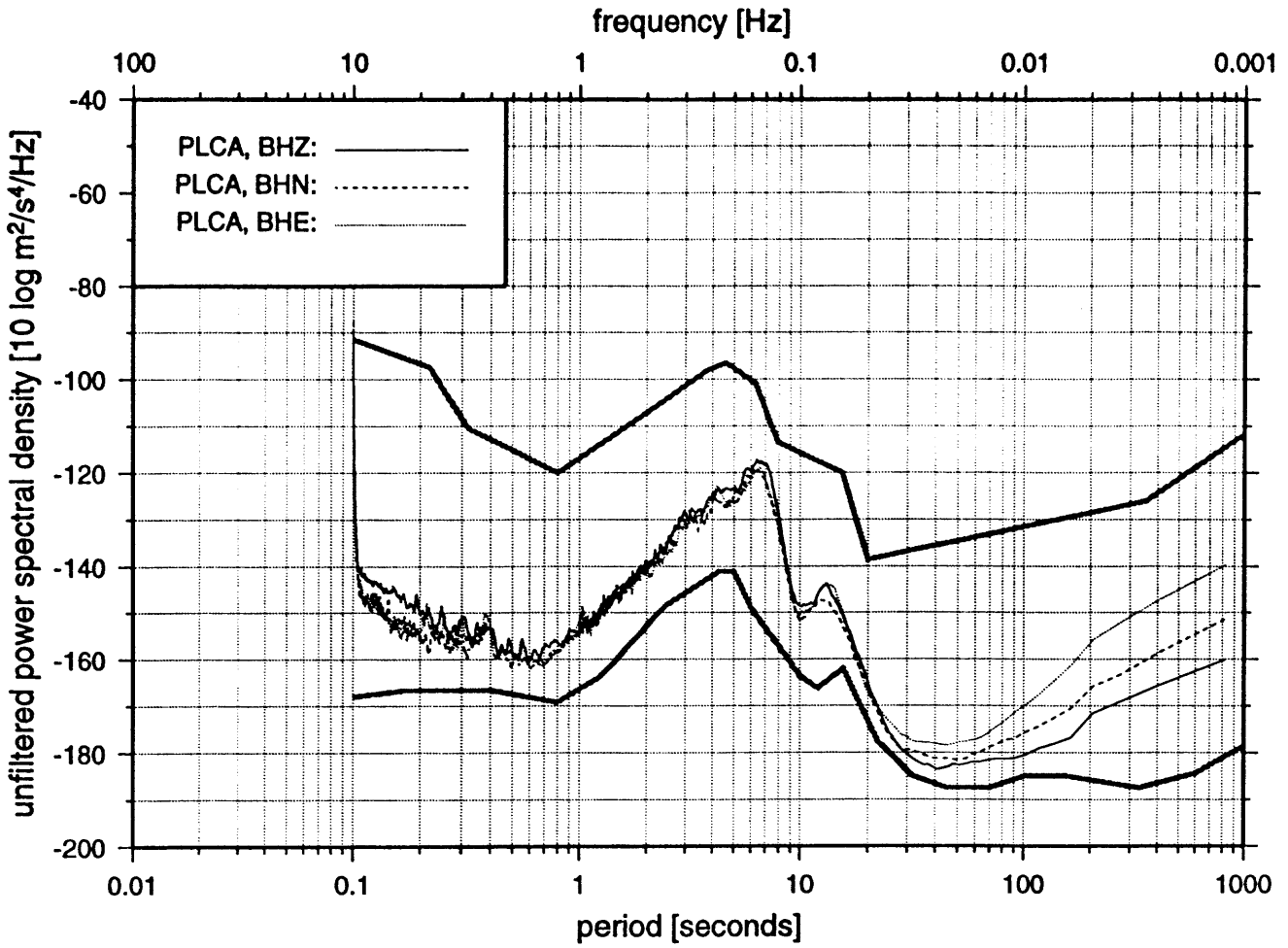


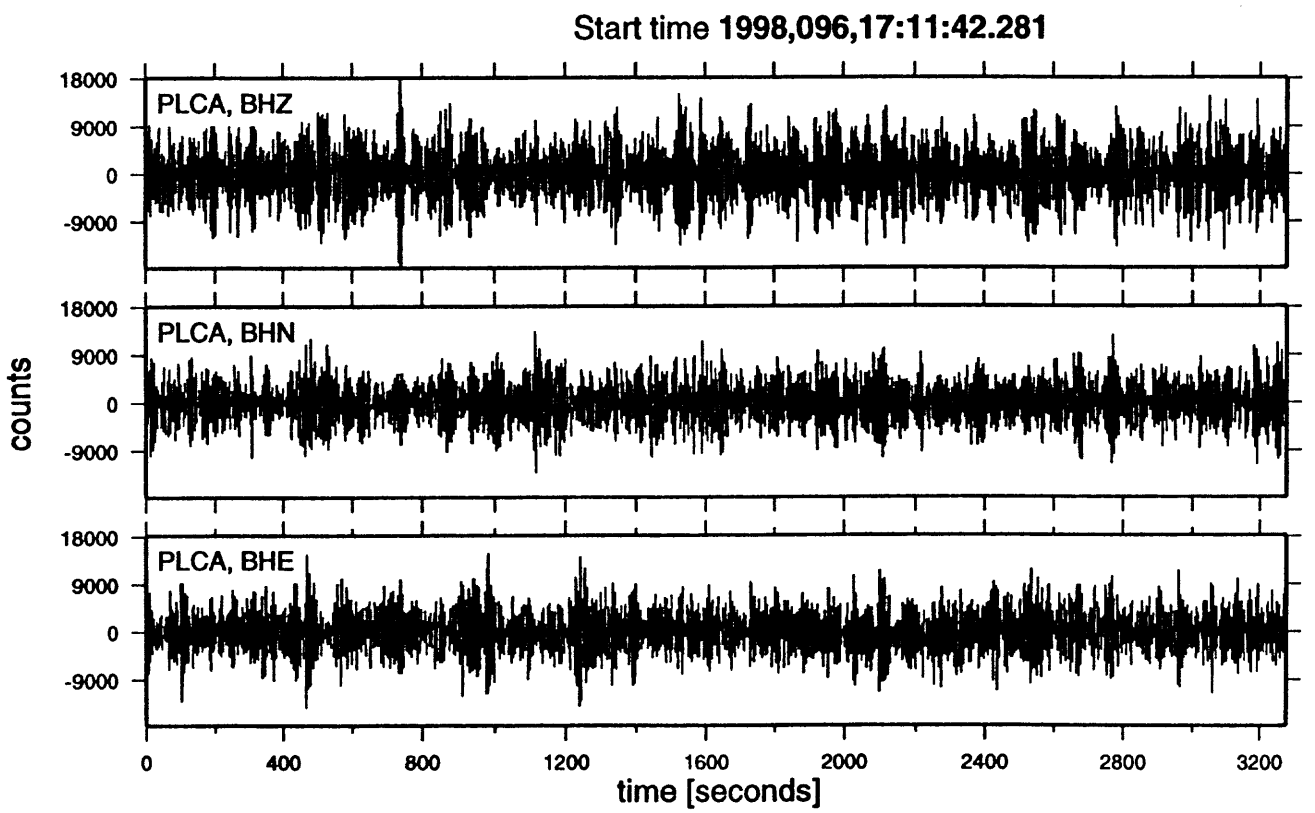
0. start time: 1998,096,17:11:42.281 length: 1.5 hours (demean) (lp co 0.0500 n 4) 5261.

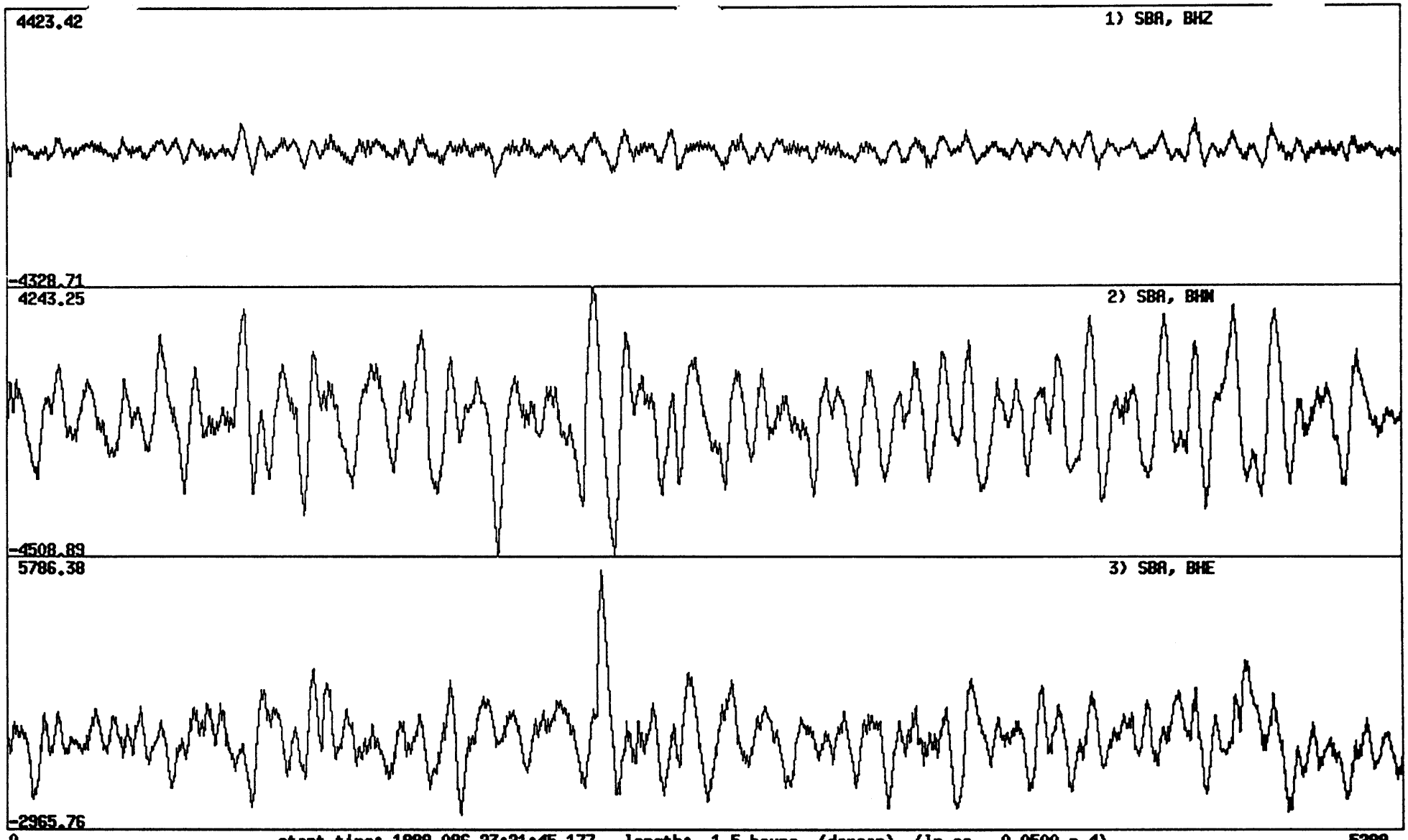
GFS file: tele.gfs
min and max (<ret> for auto-scale) : -30000 30000
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlin B) ylin

Seismic Spectra and Waveform Plot

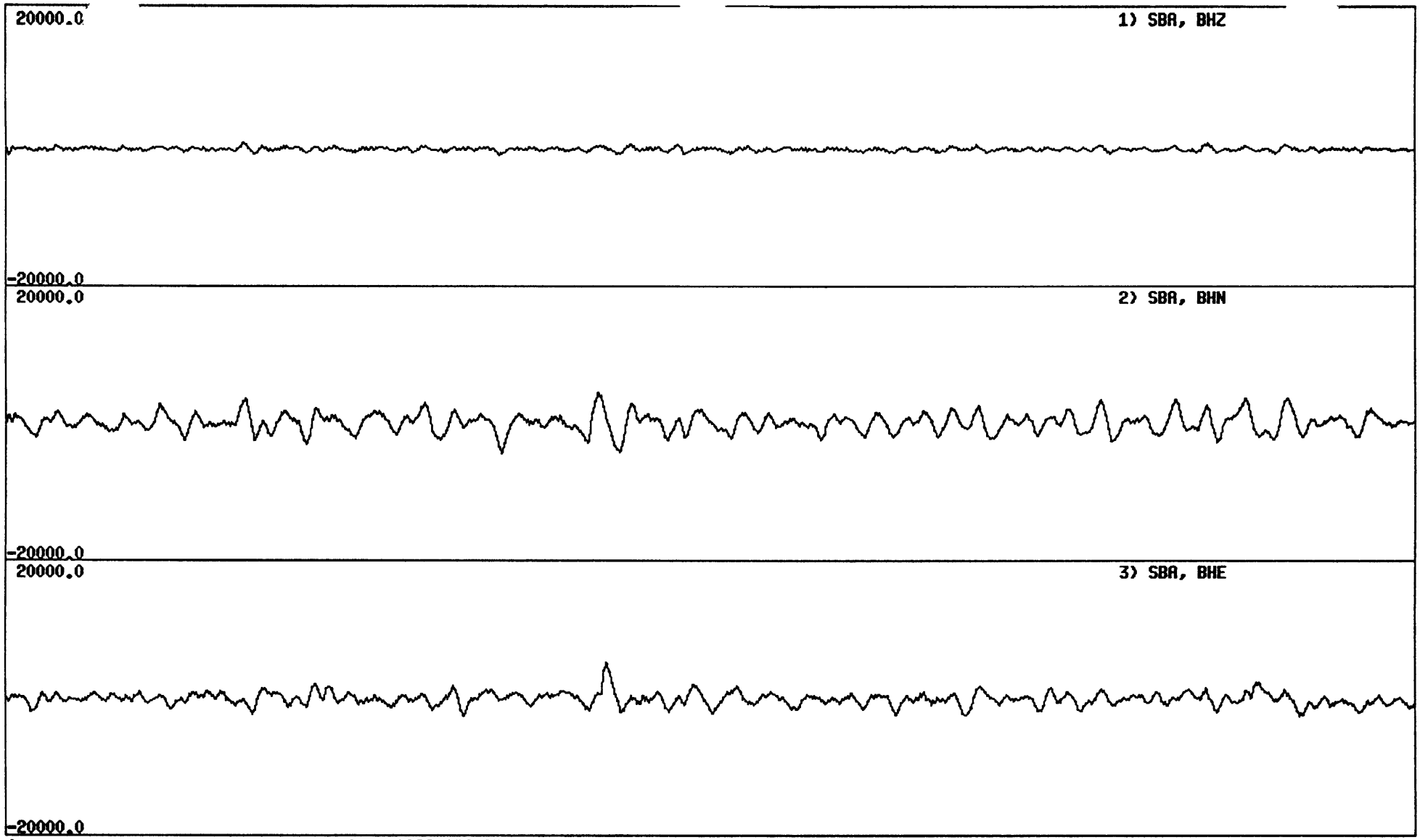






station: SBA channels: BHE BHN BHZ
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

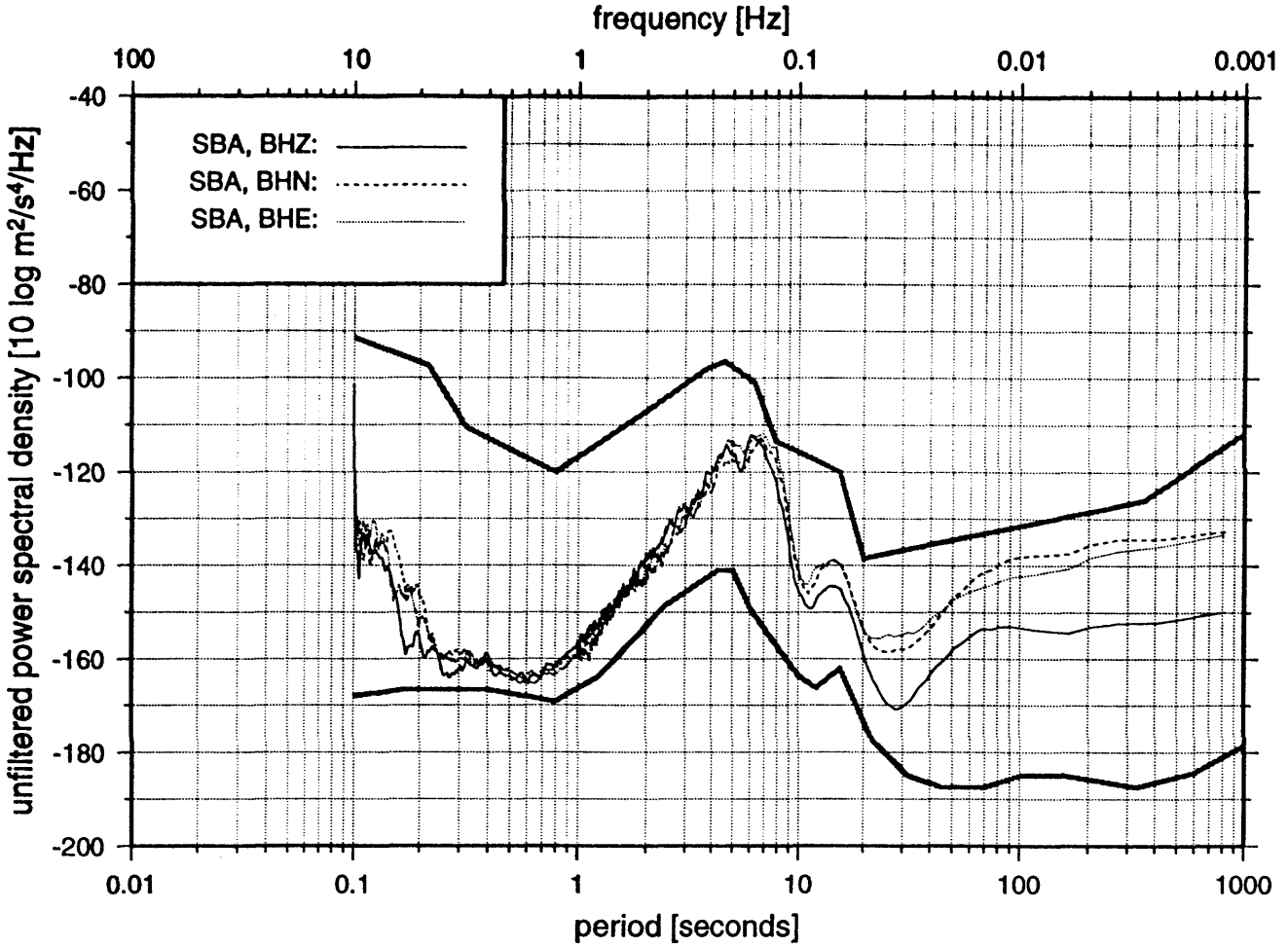


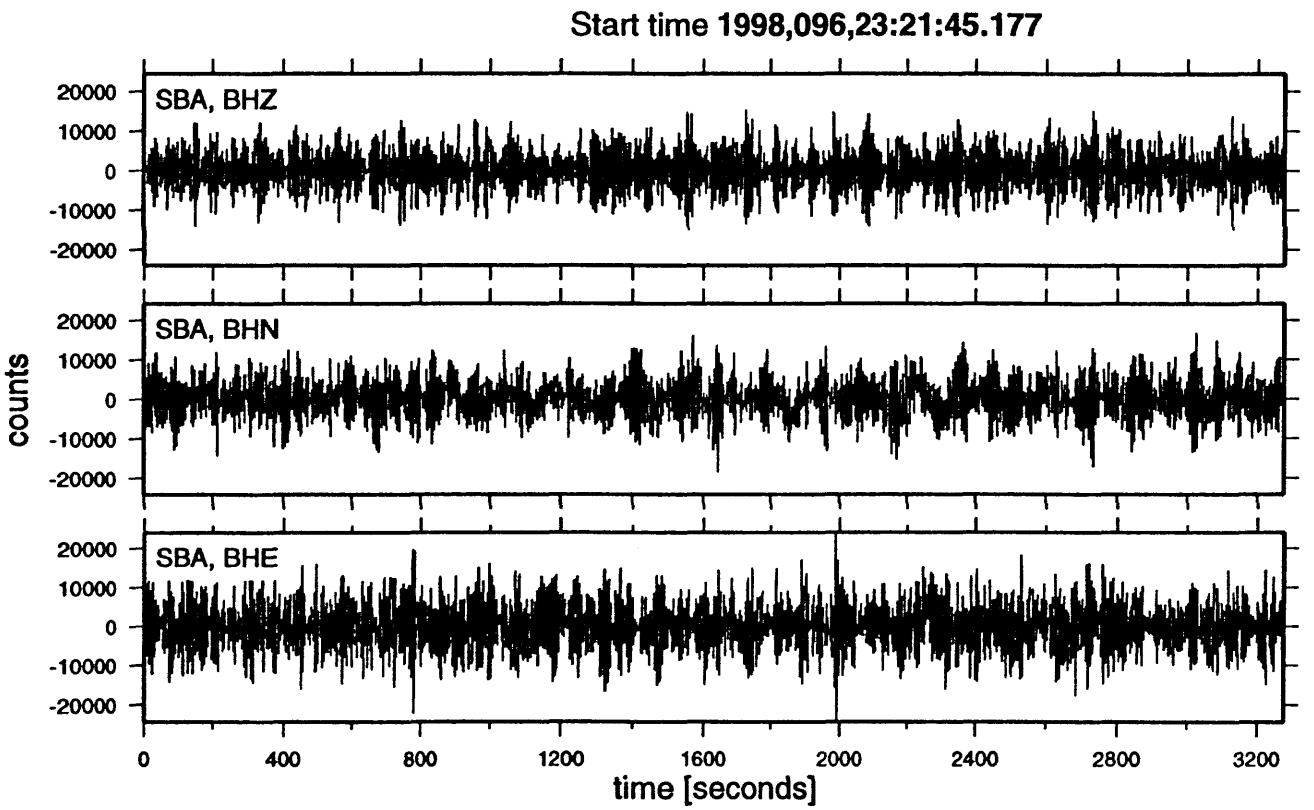
0. start time: 1998,096,23:21:45.177 length: 1.5 hours (demean) (lp co 0.0500 n 4) 5289.

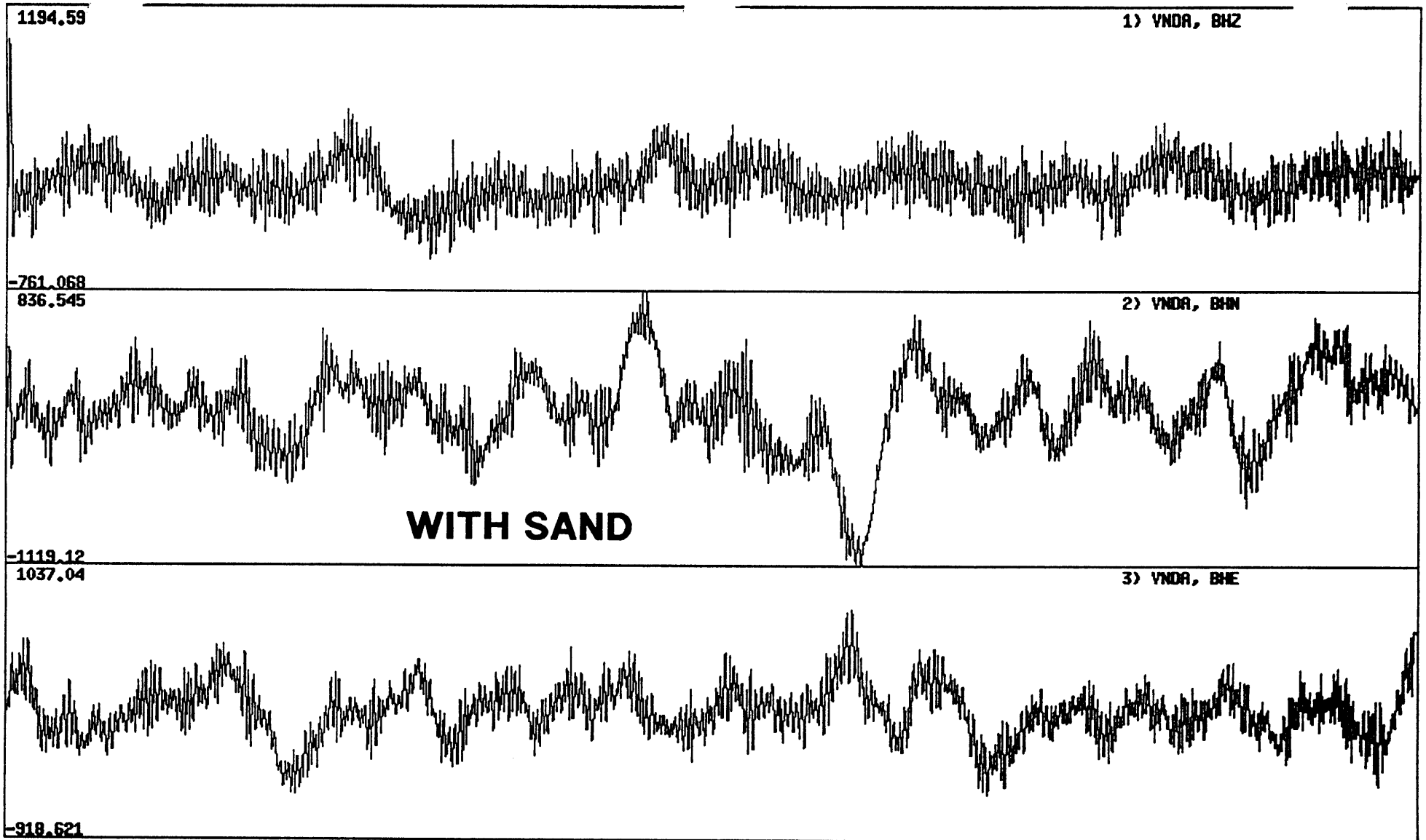
GFS file: tele.gfs
min and max (<ret> for auto-scale) : -20000 20000
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlin B) ylin

Seismic Spectra and Waveform Plot

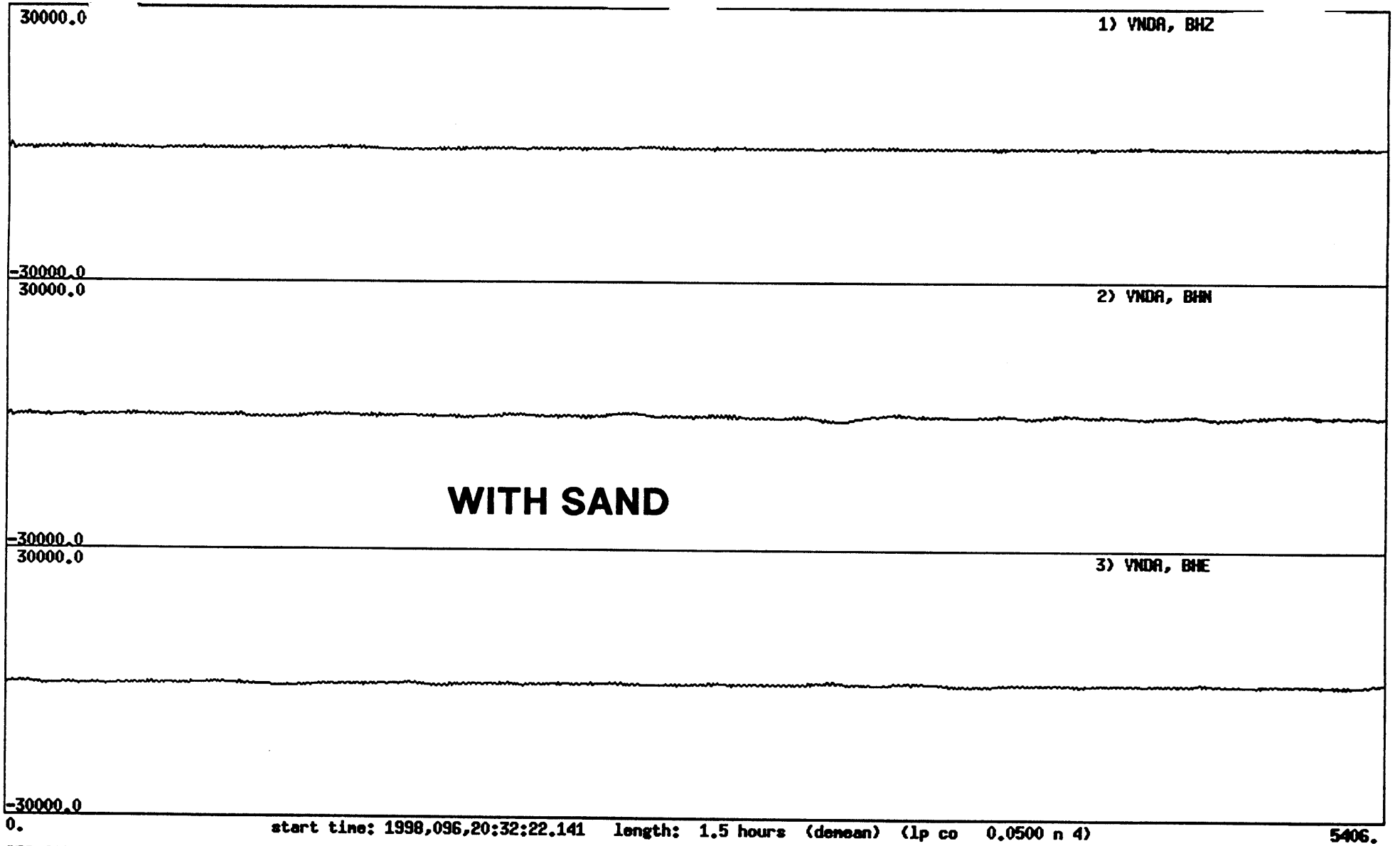






station: VNDA channels: BHE BHN BHZ
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

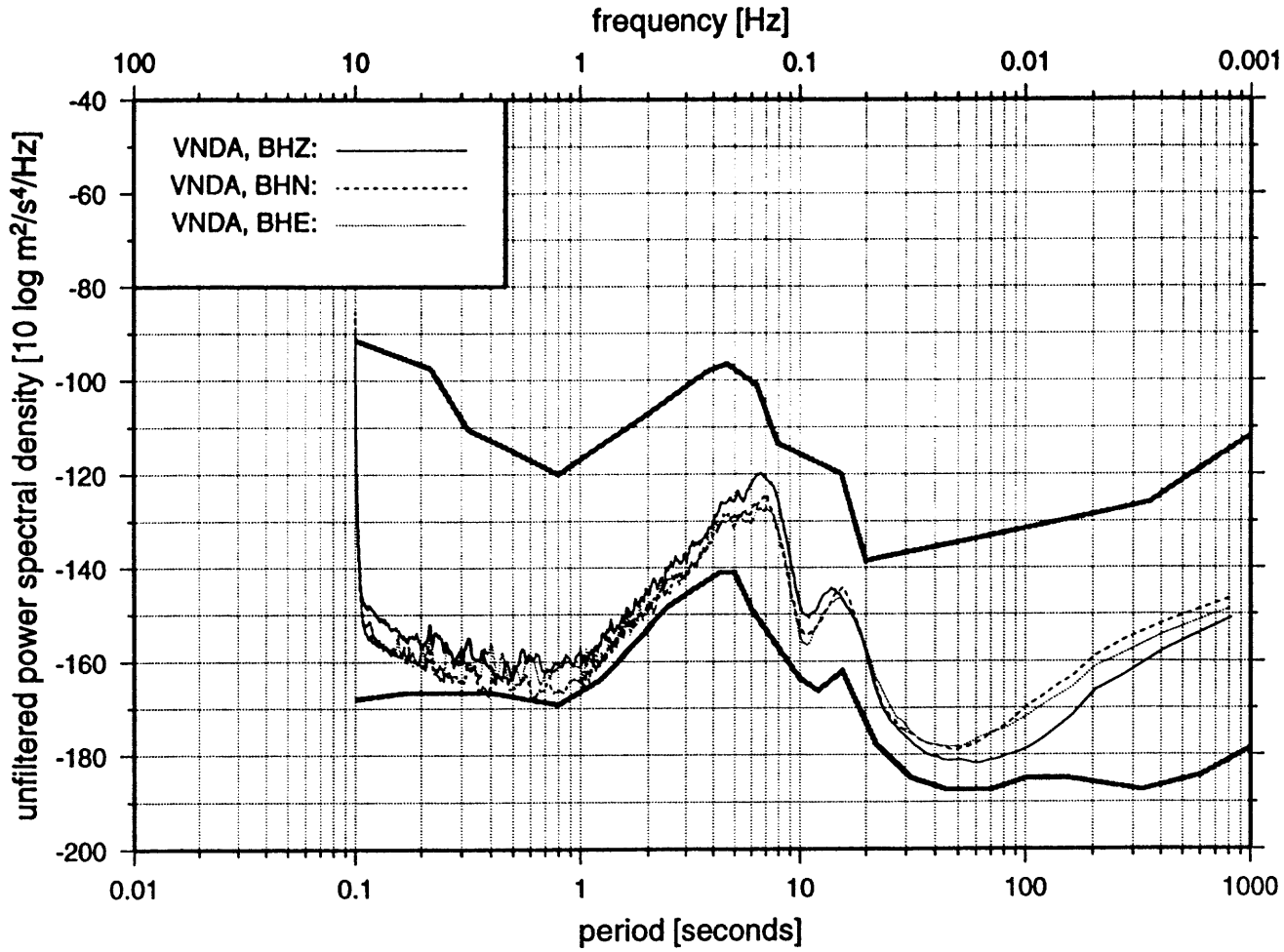
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim



GFS file: tele.gfs
min and max (<ret> for auto-scale) : -30000 30000
GFS file: tele.gfs

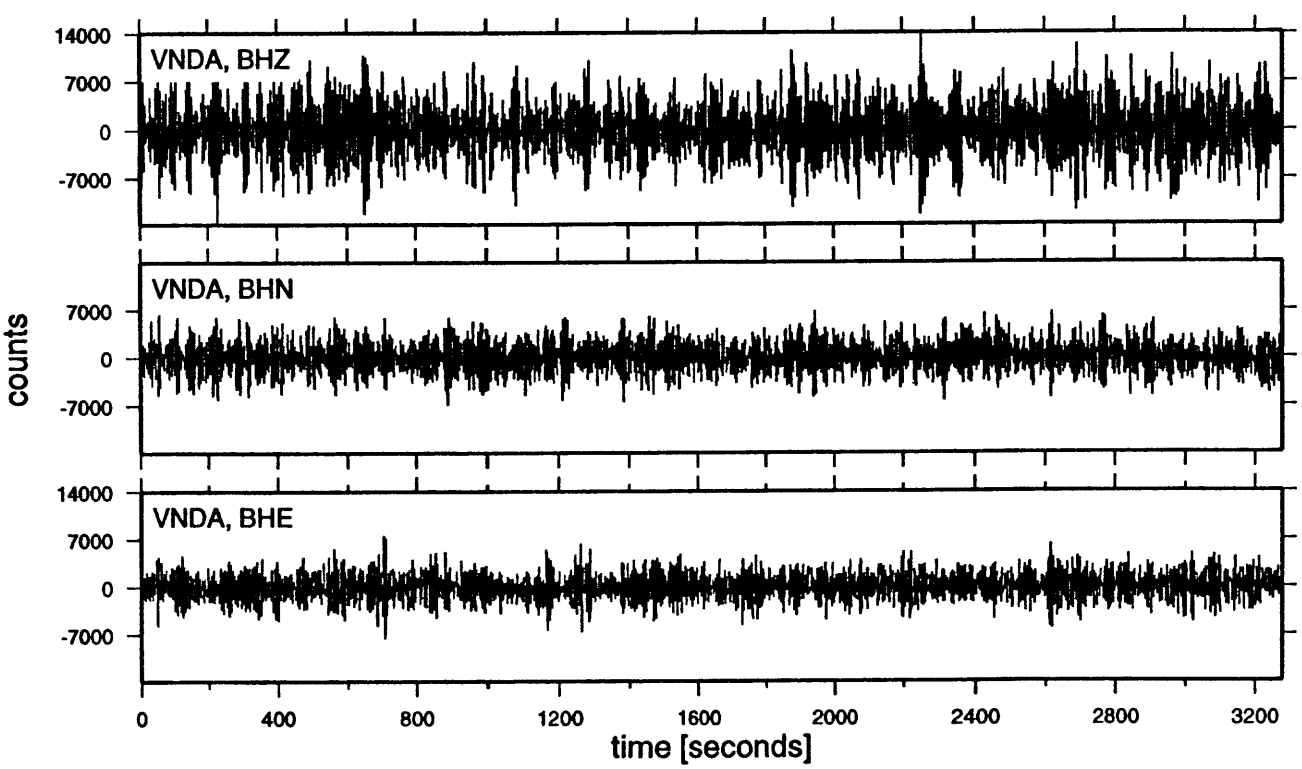
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

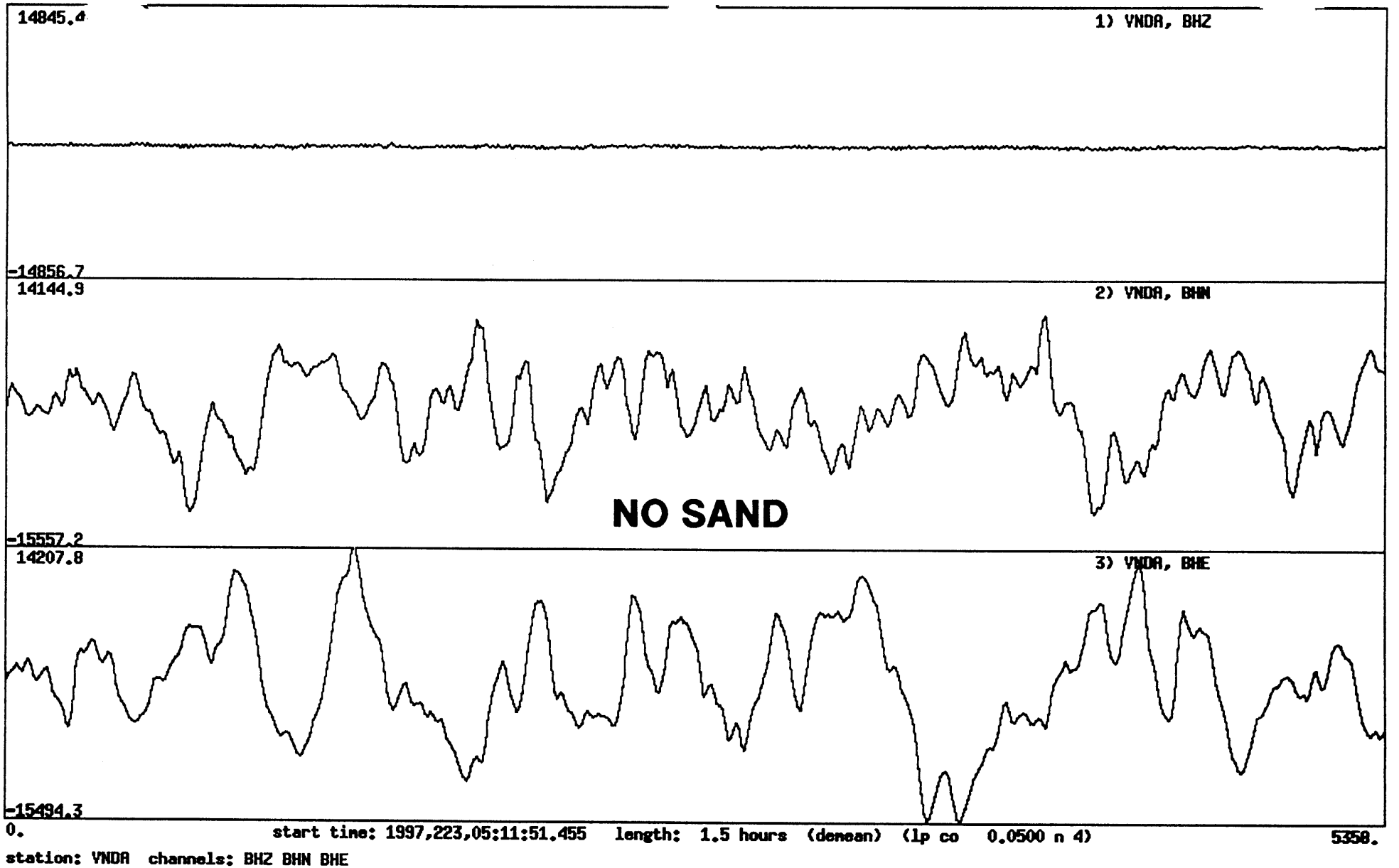
Seismic Spectra and Waveform Plot



WITH SAND

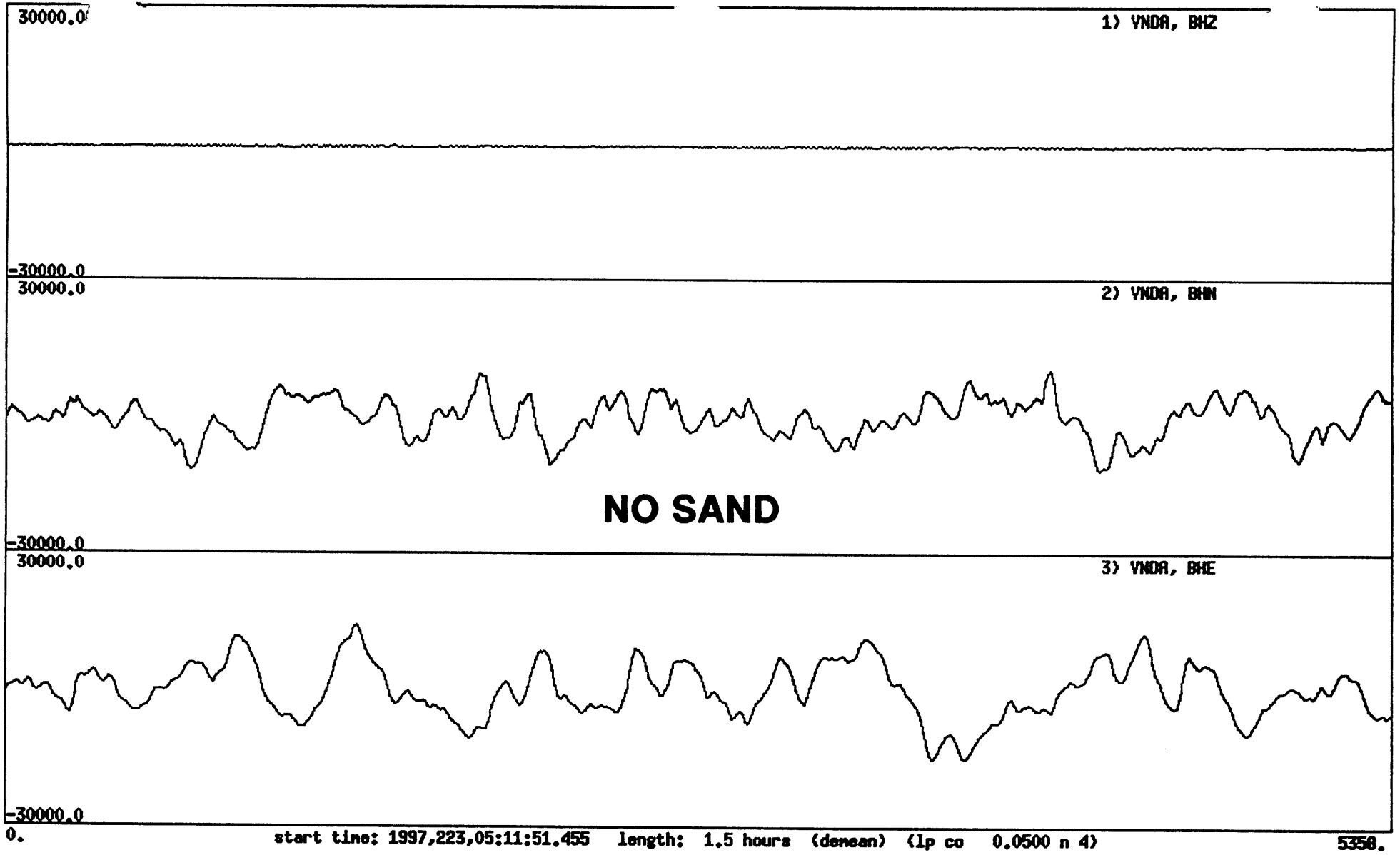
Start time **1998,096,20:32:22.141**





station: VNDA channels: BHZ BHN BHE
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: hutt_aftac.gfs

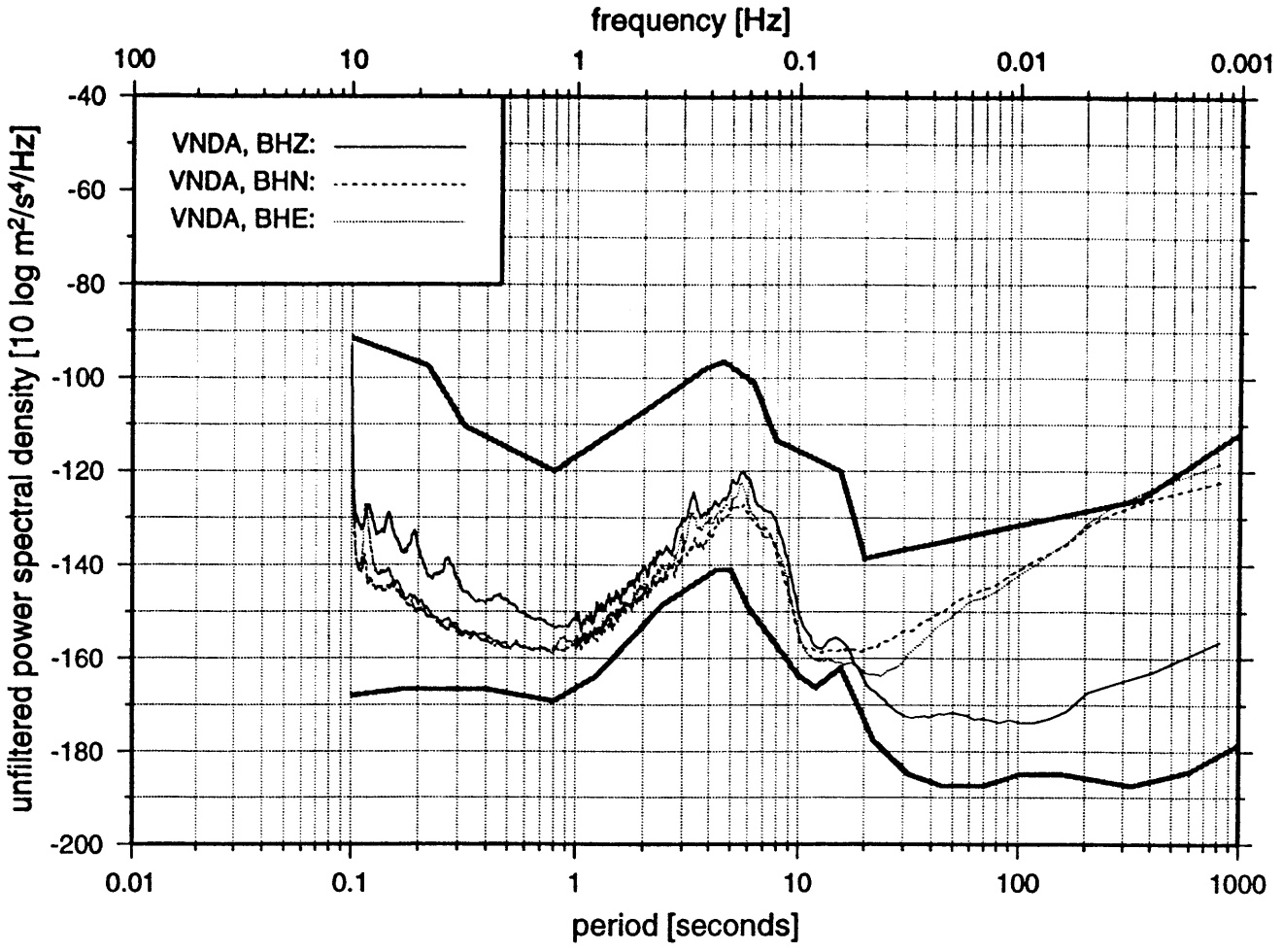
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim



GFS file: hutt_aftac.gfs
min and max (<ret> for auto-scale) : -30000 30000
GFS file: hutt_aftac.gfs

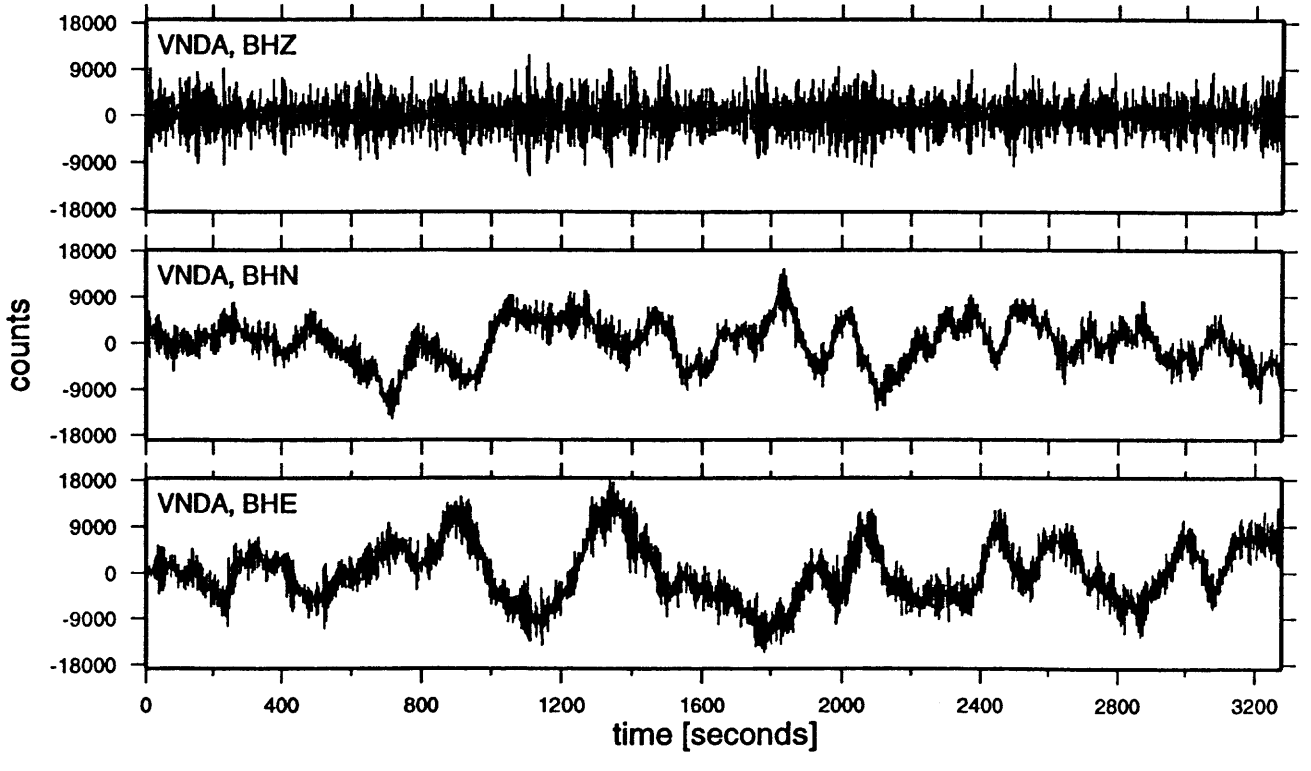
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlin B) ylin

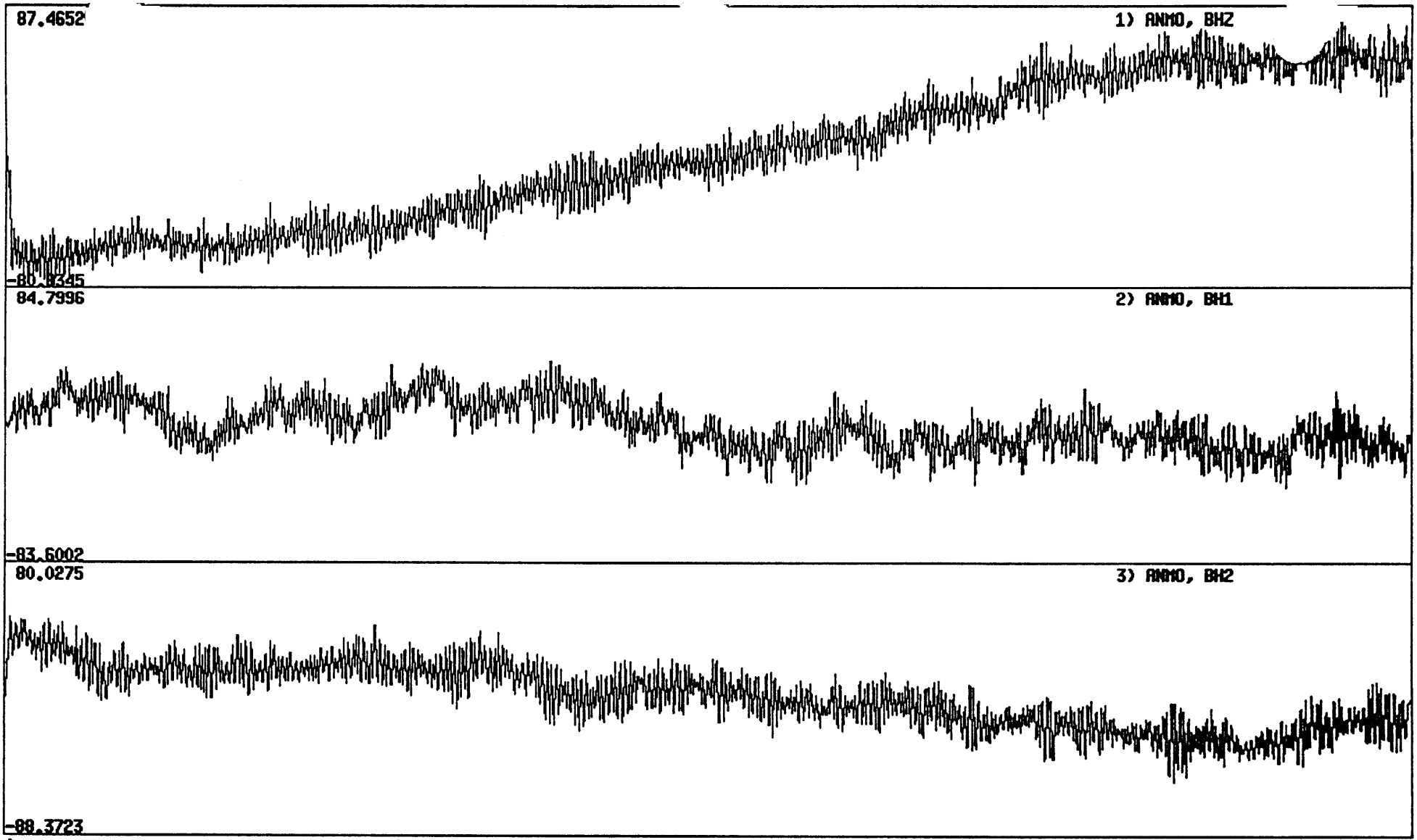
Seismic Spectra and Waveform Plot



NO SAND

Start time **1997,223,05:11:51.455**

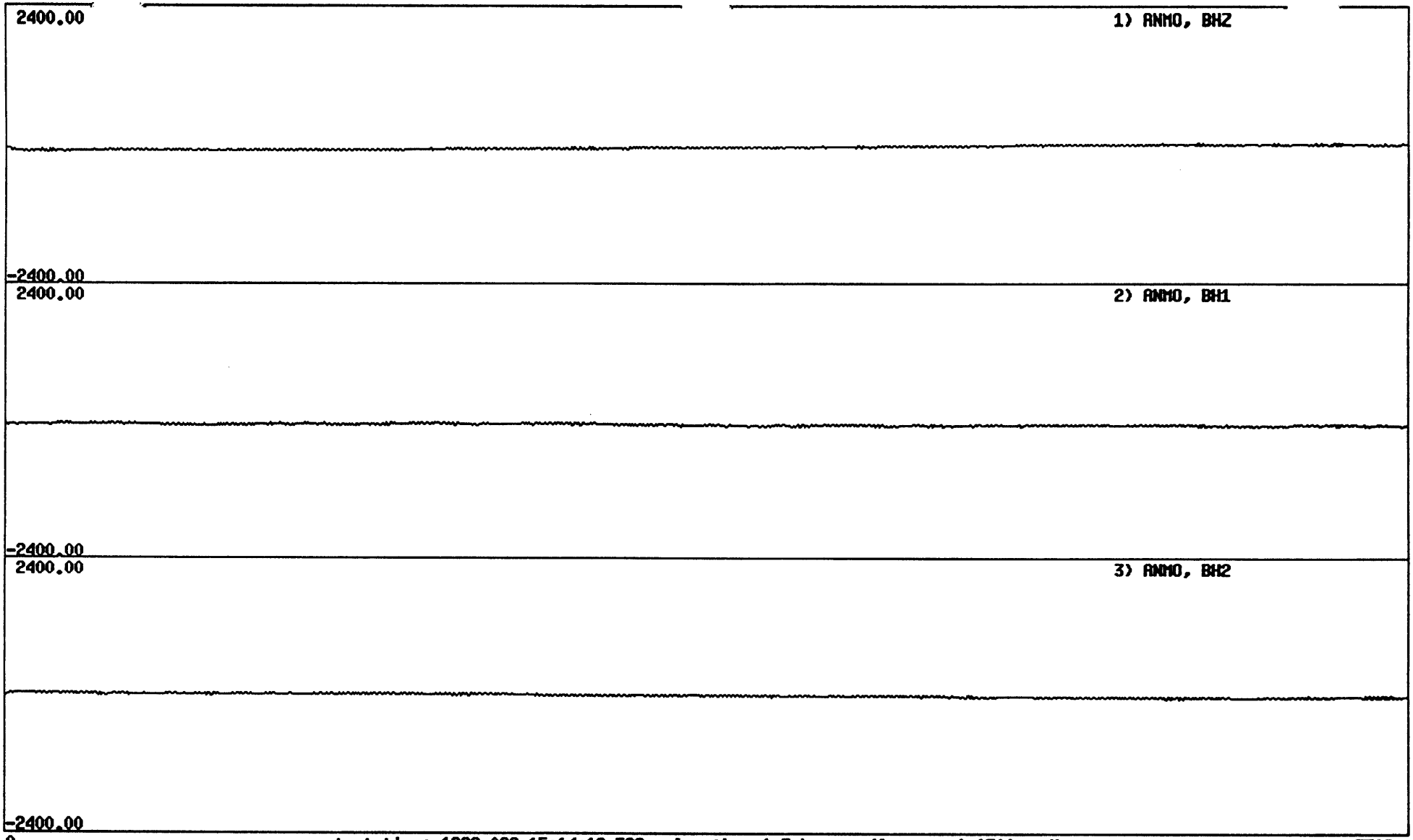




0. start time: 1998,096,15:14:18.566 length: 1.5 hours (lp co 0.0500 n 4) 5509.

filter options (1=lp, 2=hp, 3=bp): 1 .05 4
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

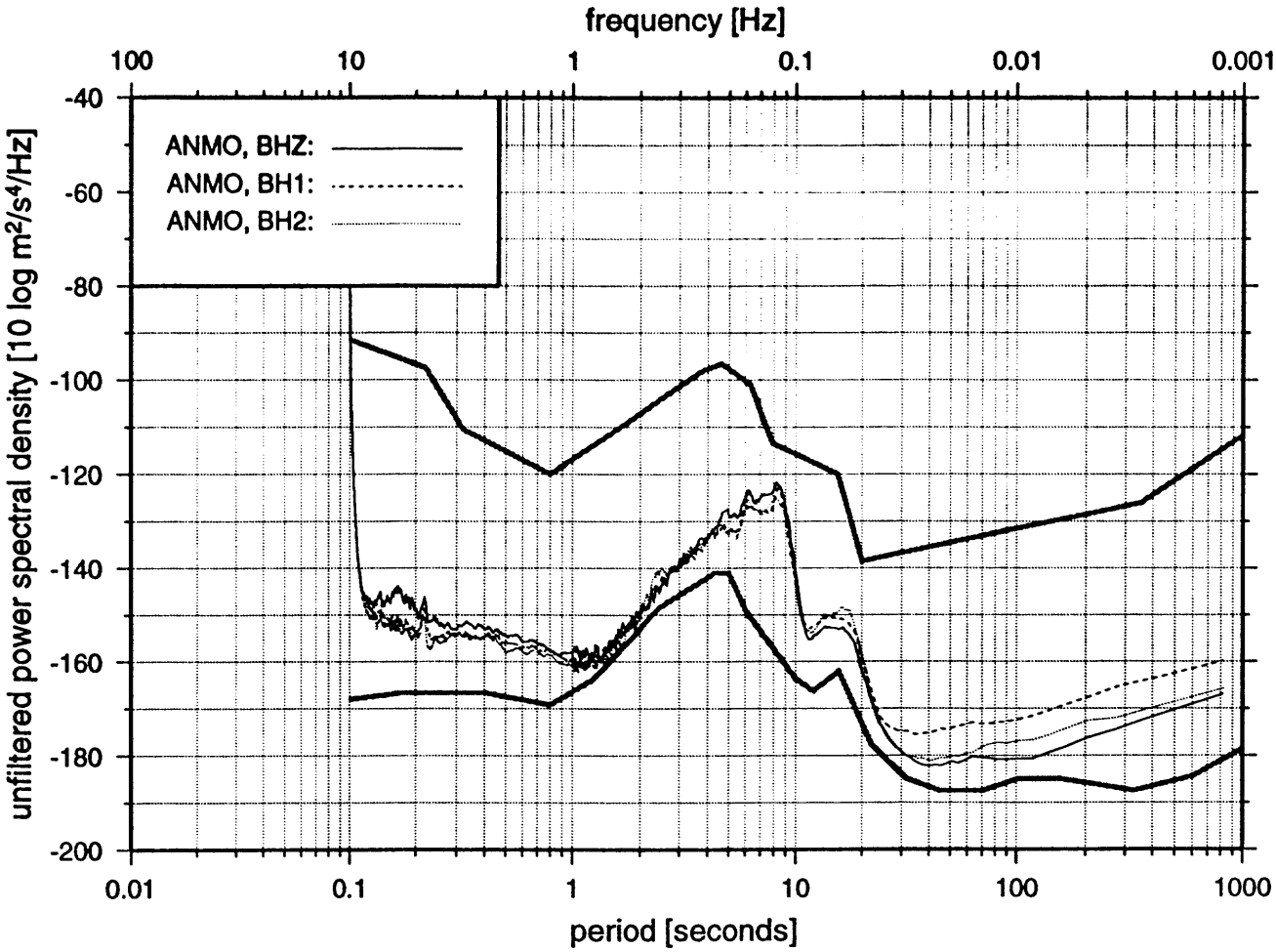
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlin B) ylin

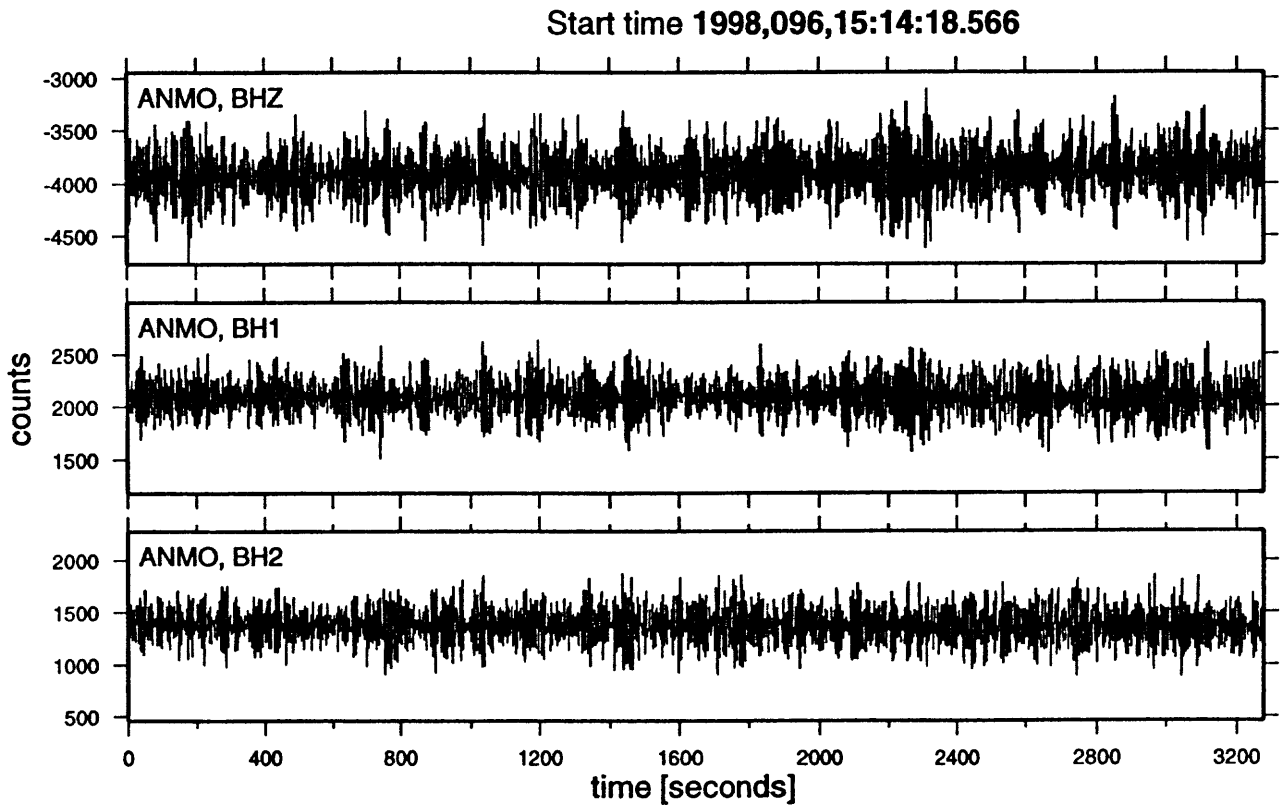


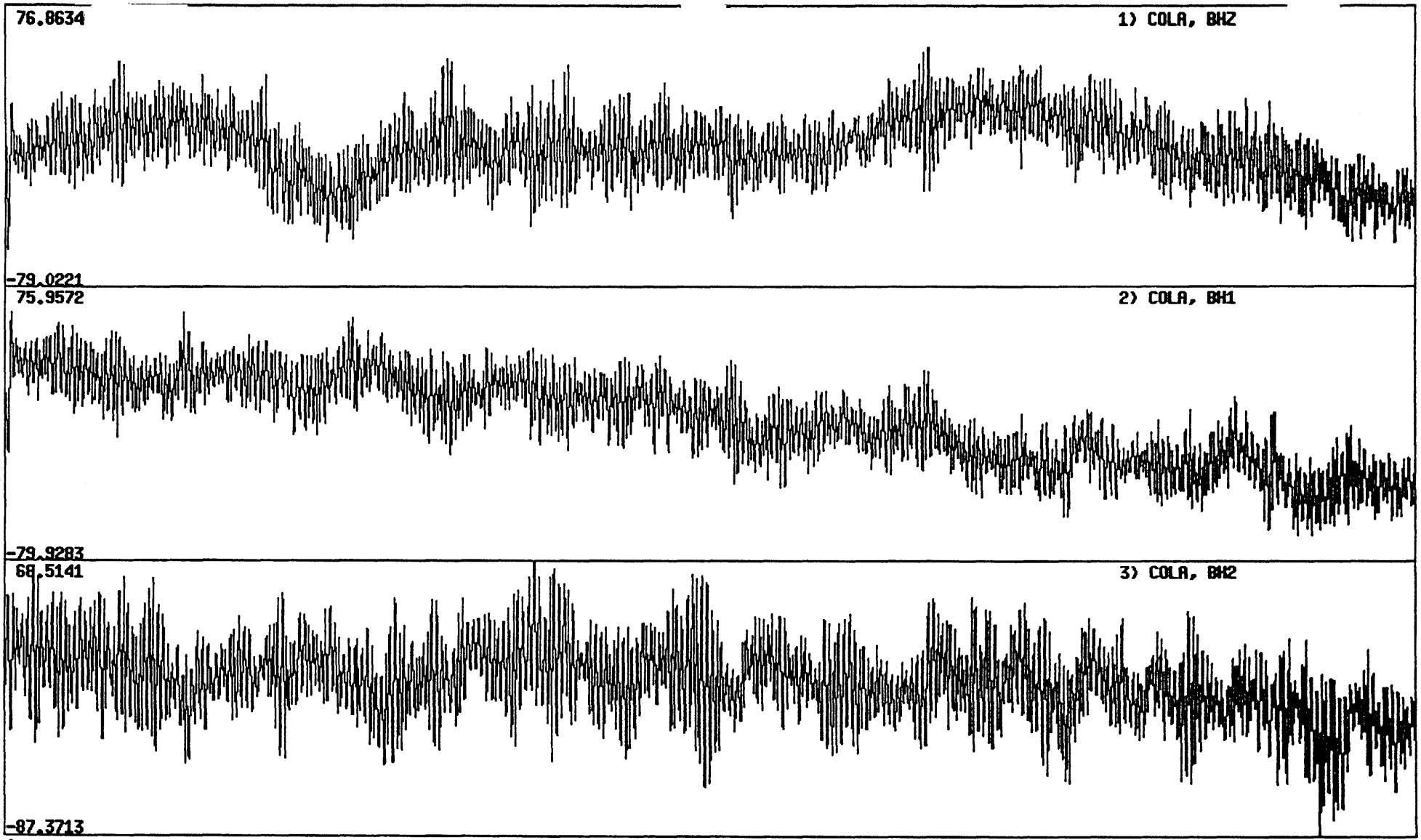
GFS file: tele.gfs
min and max (<ret> for auto-scale) : -2400 2400
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlin B) ylin

Seismic Spectra and Waveform Plot

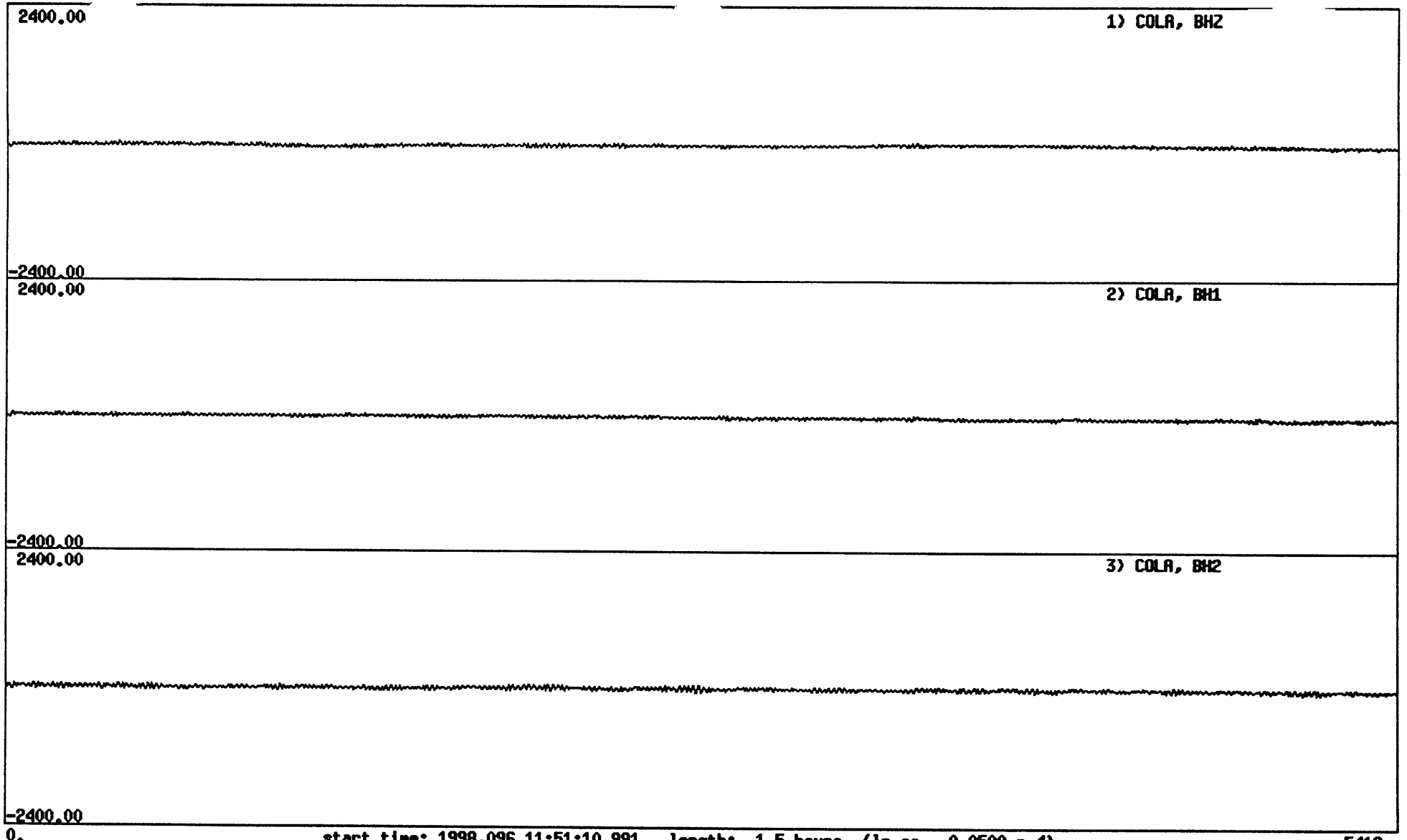






station: COLA channels: BH1 BH2 BHZ
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

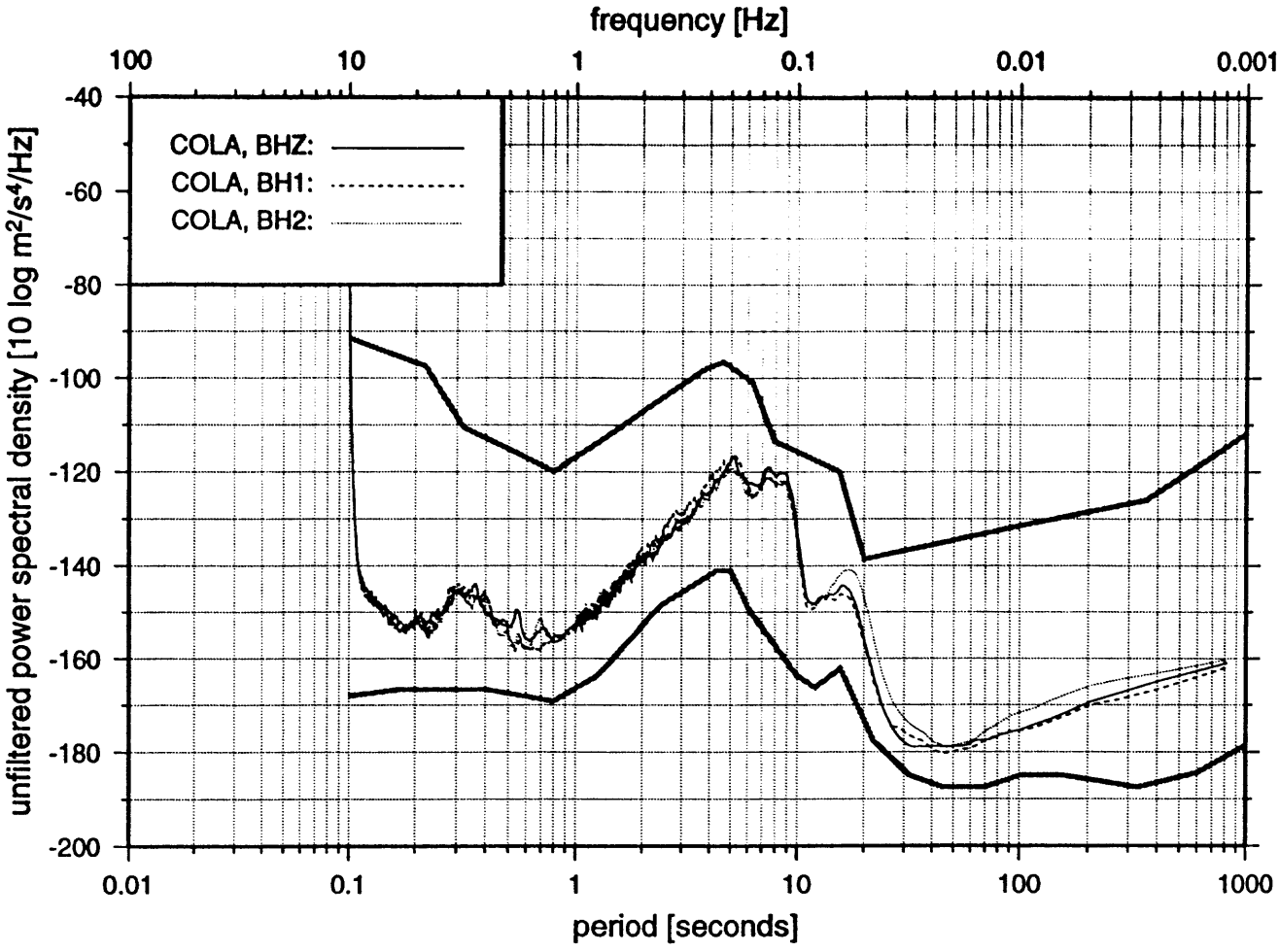
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

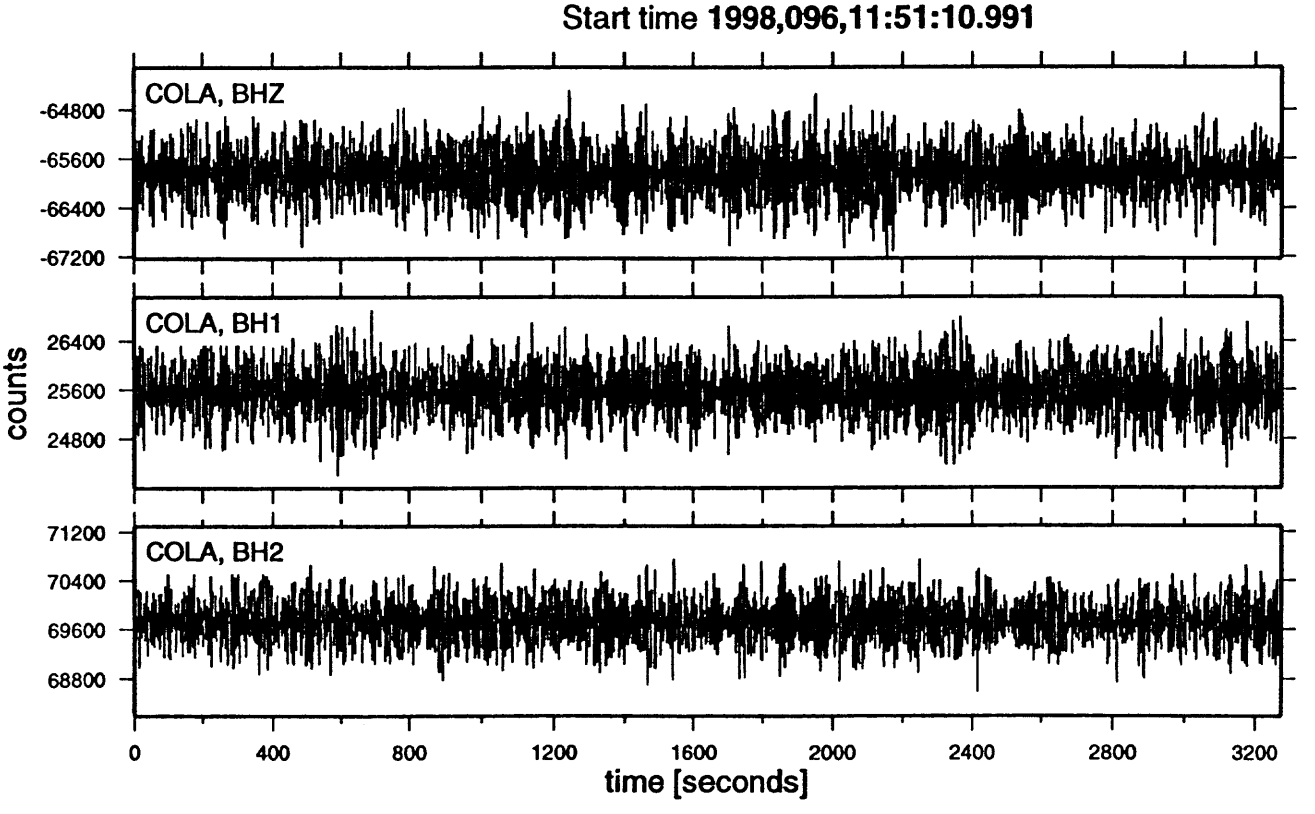


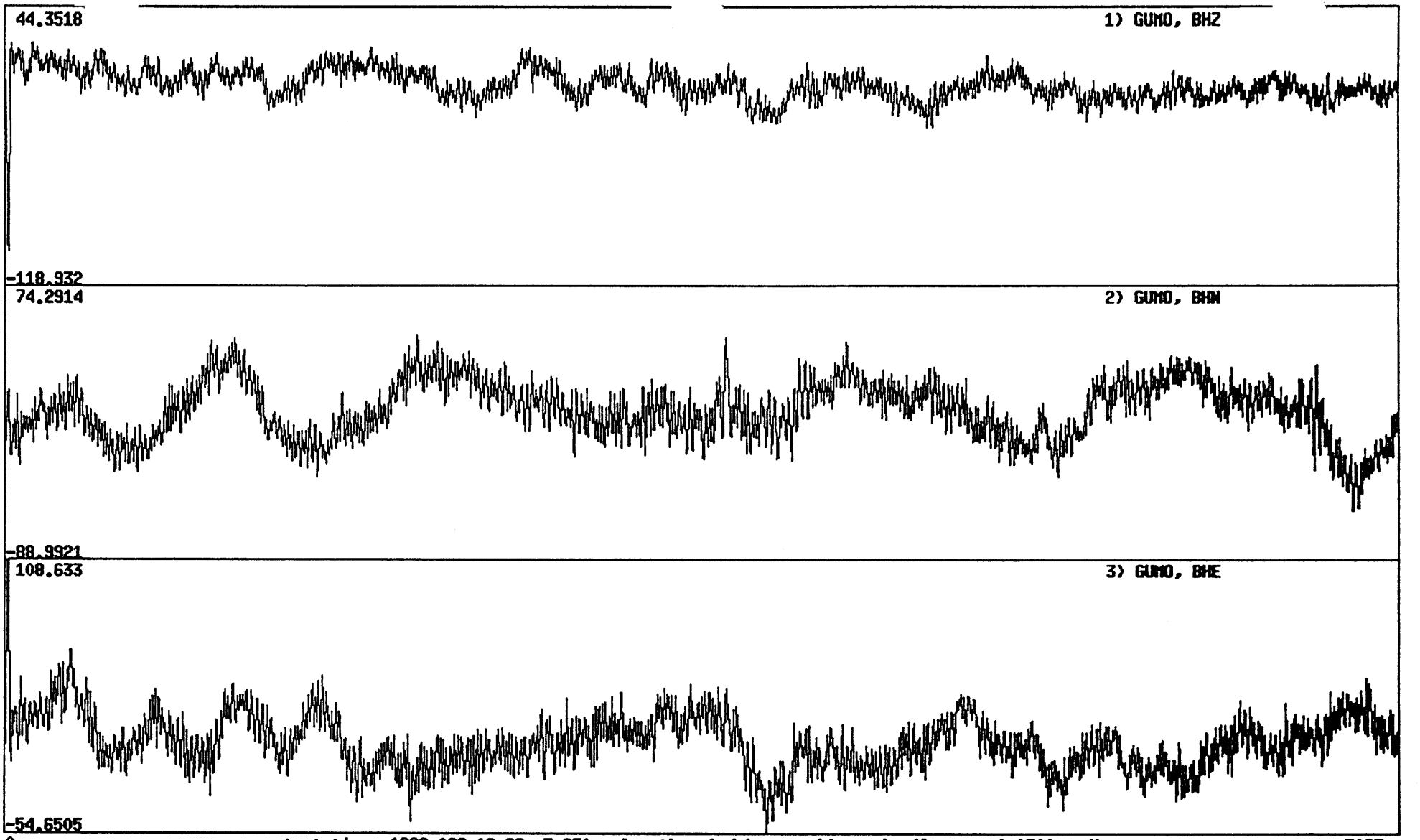
GFS file: tele.gfs
min and max (<ret> for auto-scale) : -2400 2400
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlin B) ylin

Seismic Spectra and Waveform Plot

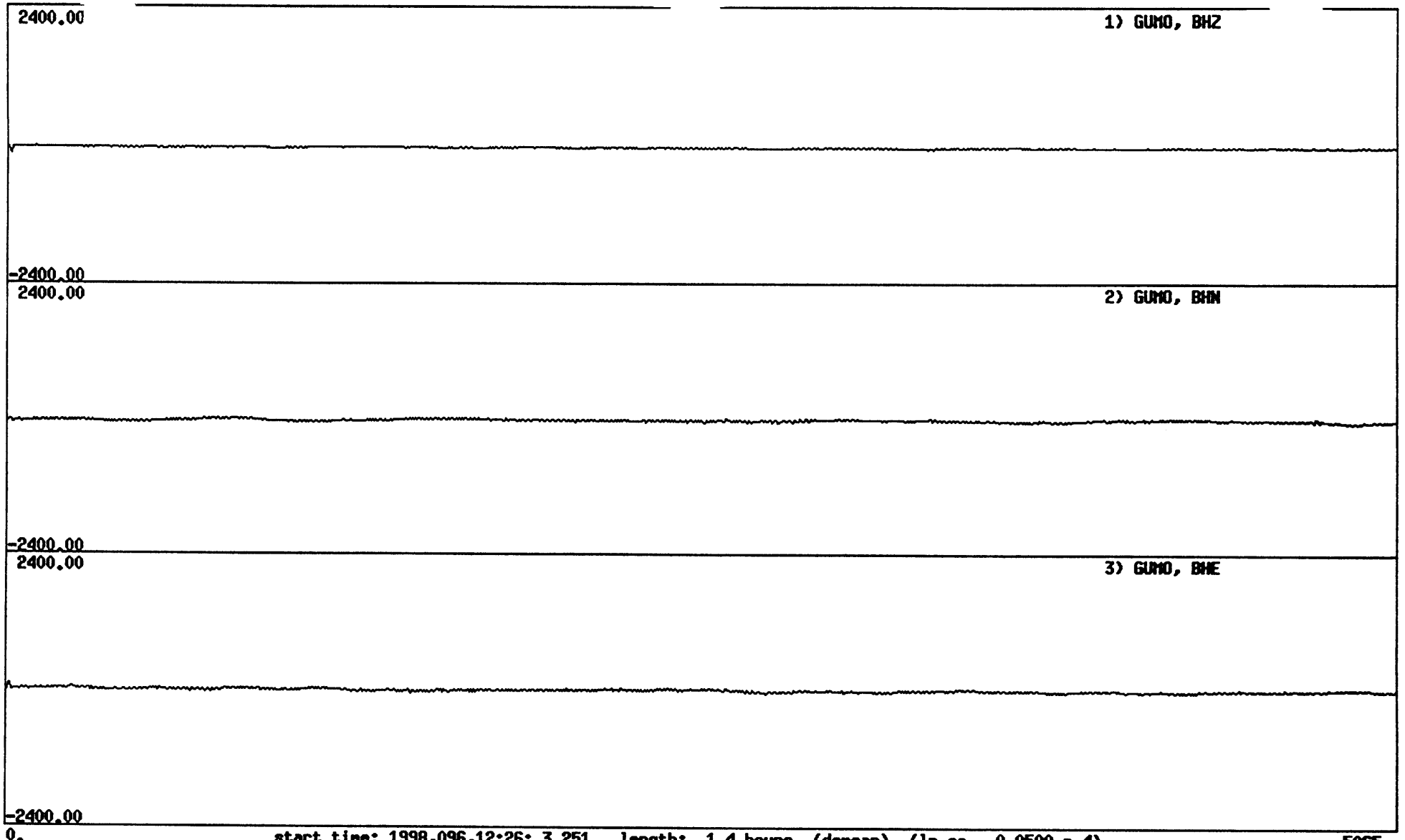






station: GUMO channels: BHE BHN BHZ
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

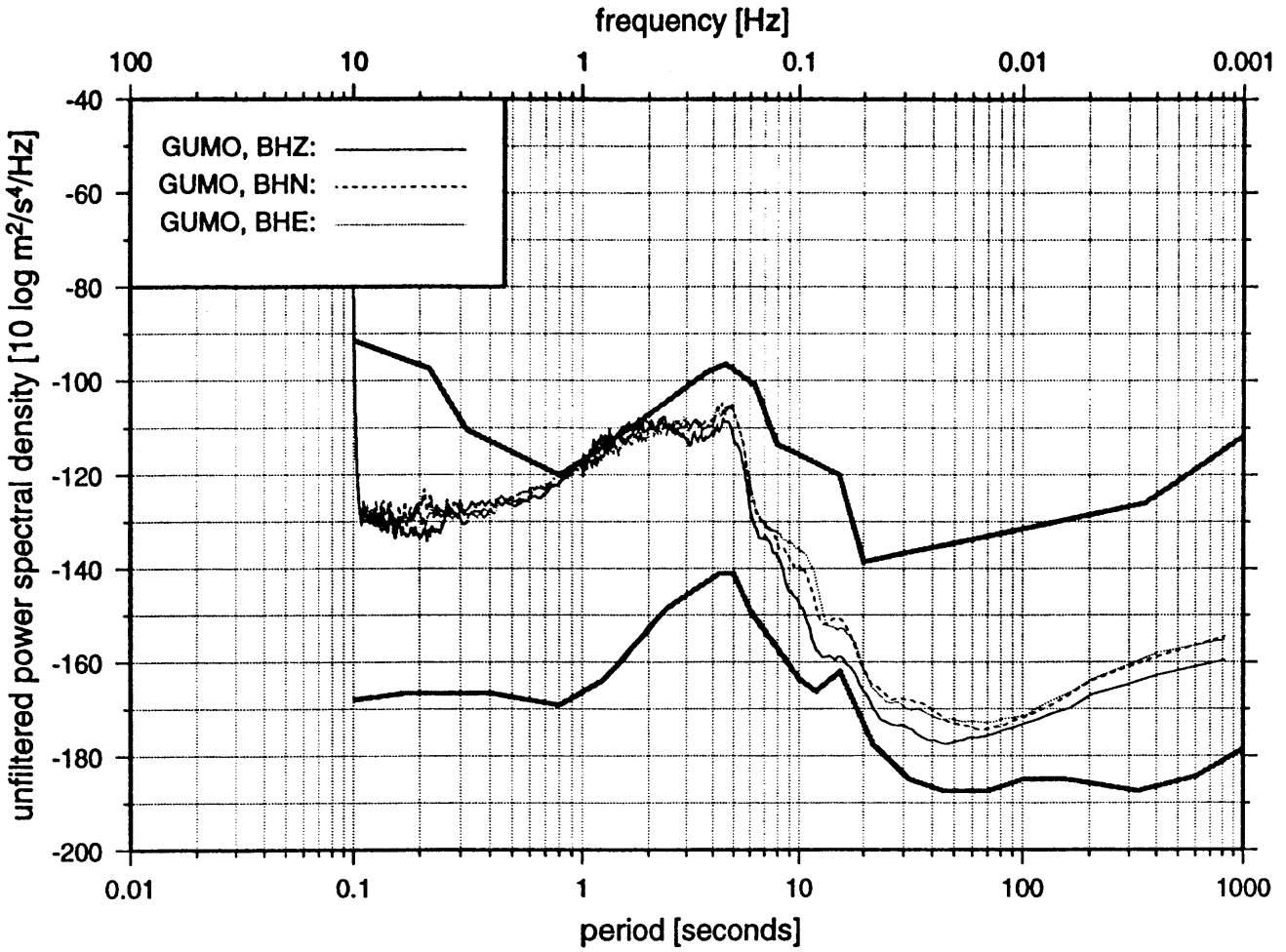
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

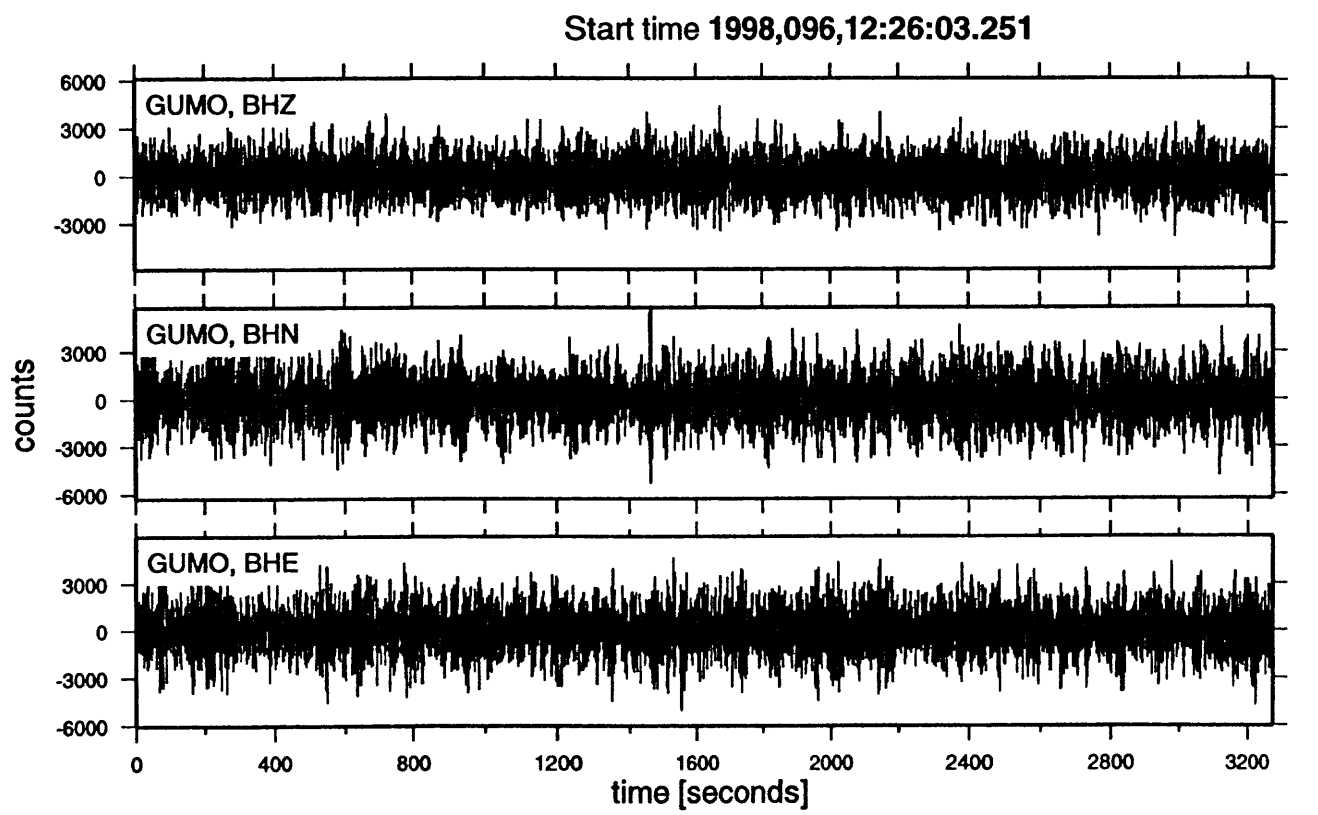


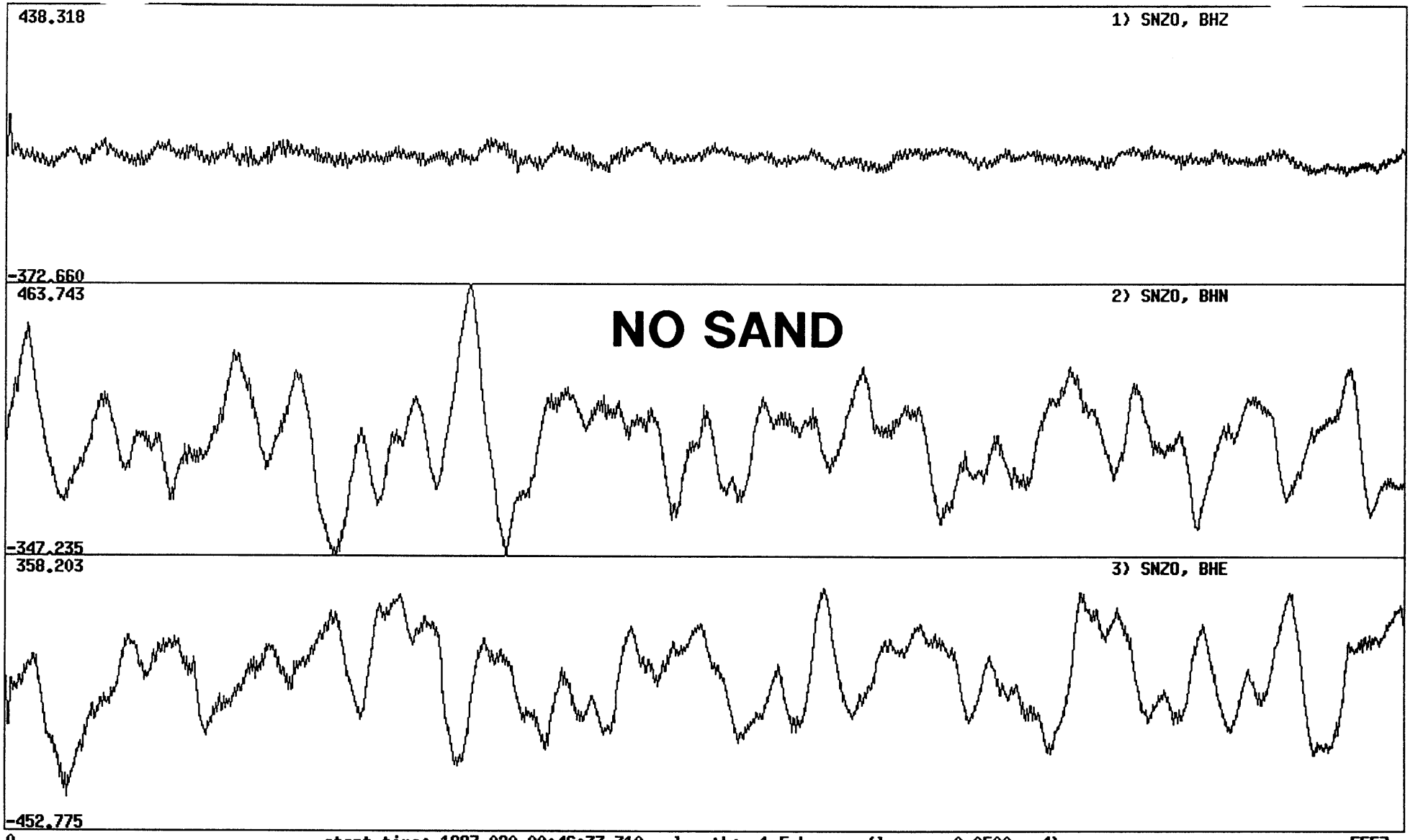
GFS file: tele.gfs
min and max (<ret> for auto-scale) : -2400 2400
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

Seismic Spectra and Waveform Plot



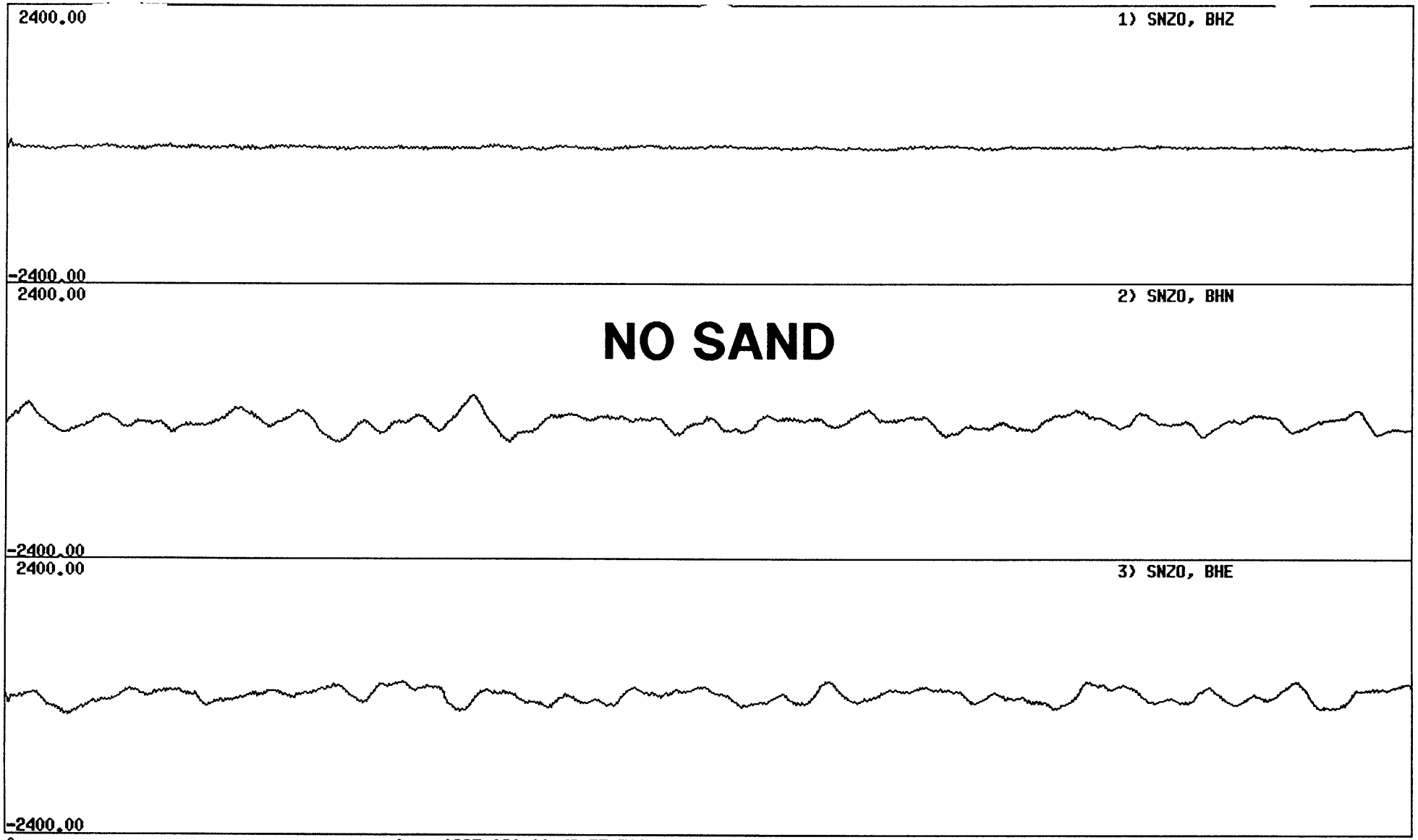




0. start time: 1997,020,00:46:33.310 length: 1.5 hours (lp co 0.0500 n 4) 5557.

station: SNZO channels: BHE BHN BHZ
GFS file: data.USER_TYLER.SNZO

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

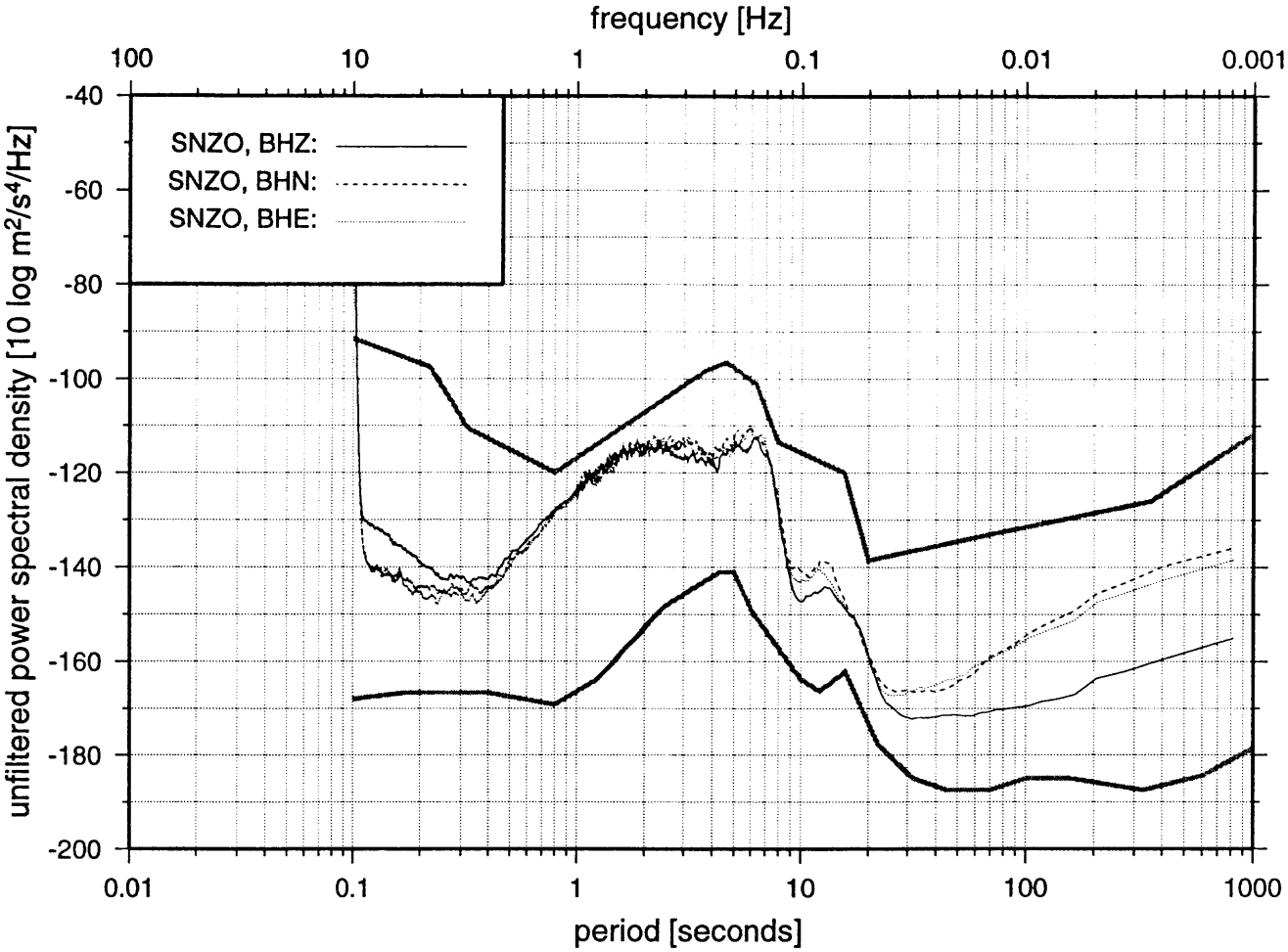


0. start time: 1997,020,00:46:33.310 length: 1.5 hours (lp co 0.0500 n 4) 5557.

GFS file: data.USER_TYLER.SNZO
min and max (<ret> for auto-scale) : -2400 2400
GFS file: data.USER_TYLER.SNZO

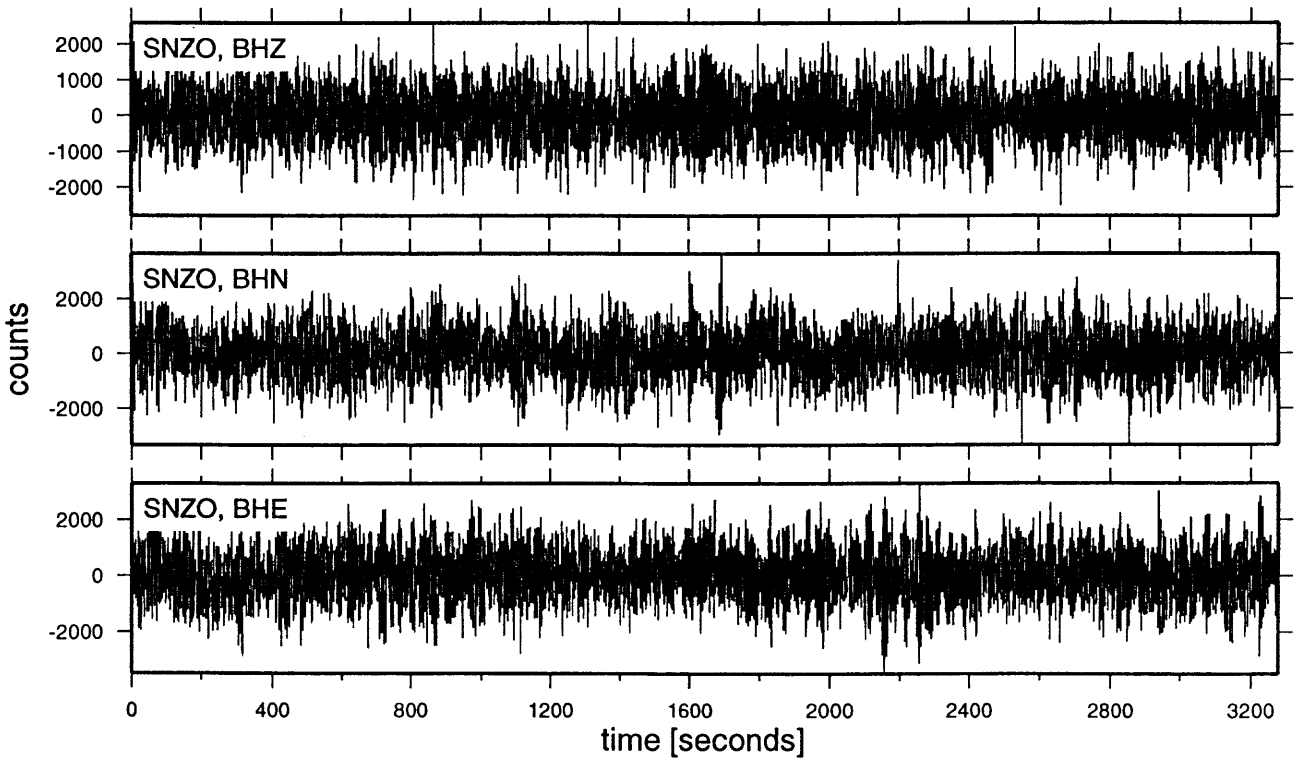
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

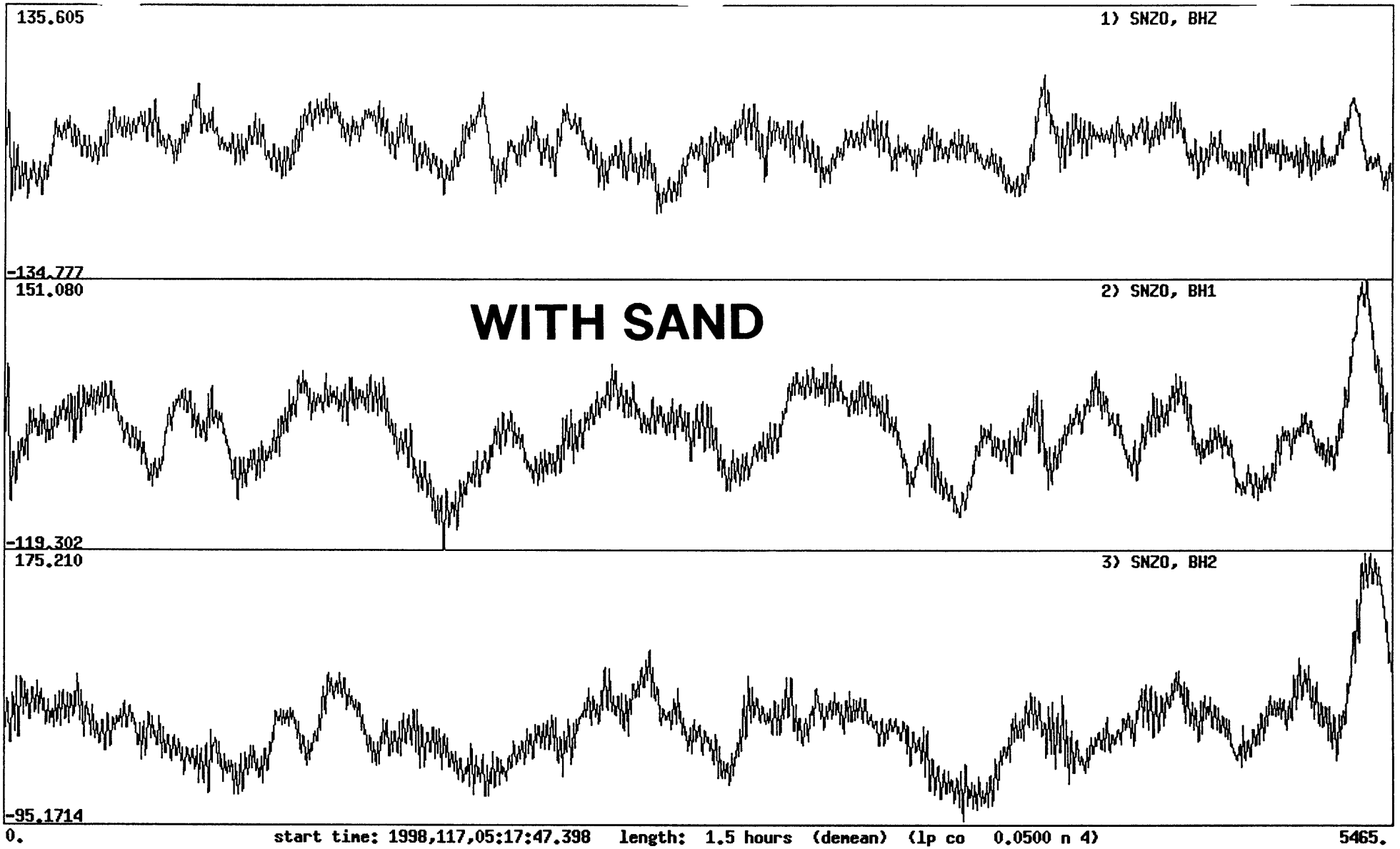
Seismic Spectra and Waveform Plot



NO SAND

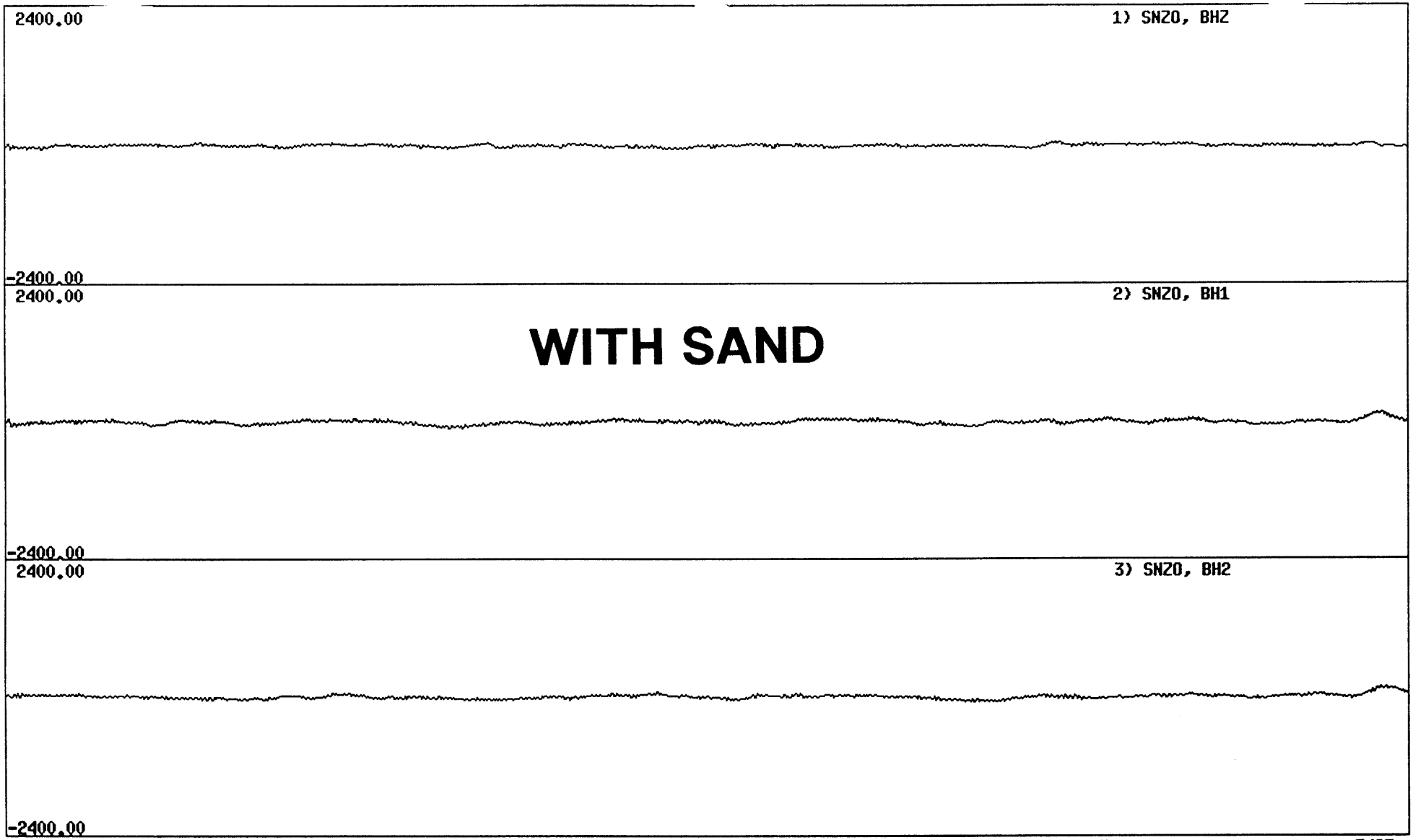
Start time **1997,020,00:46:33.310**





station: SNZO channels: BH1 BH2 BHZ
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

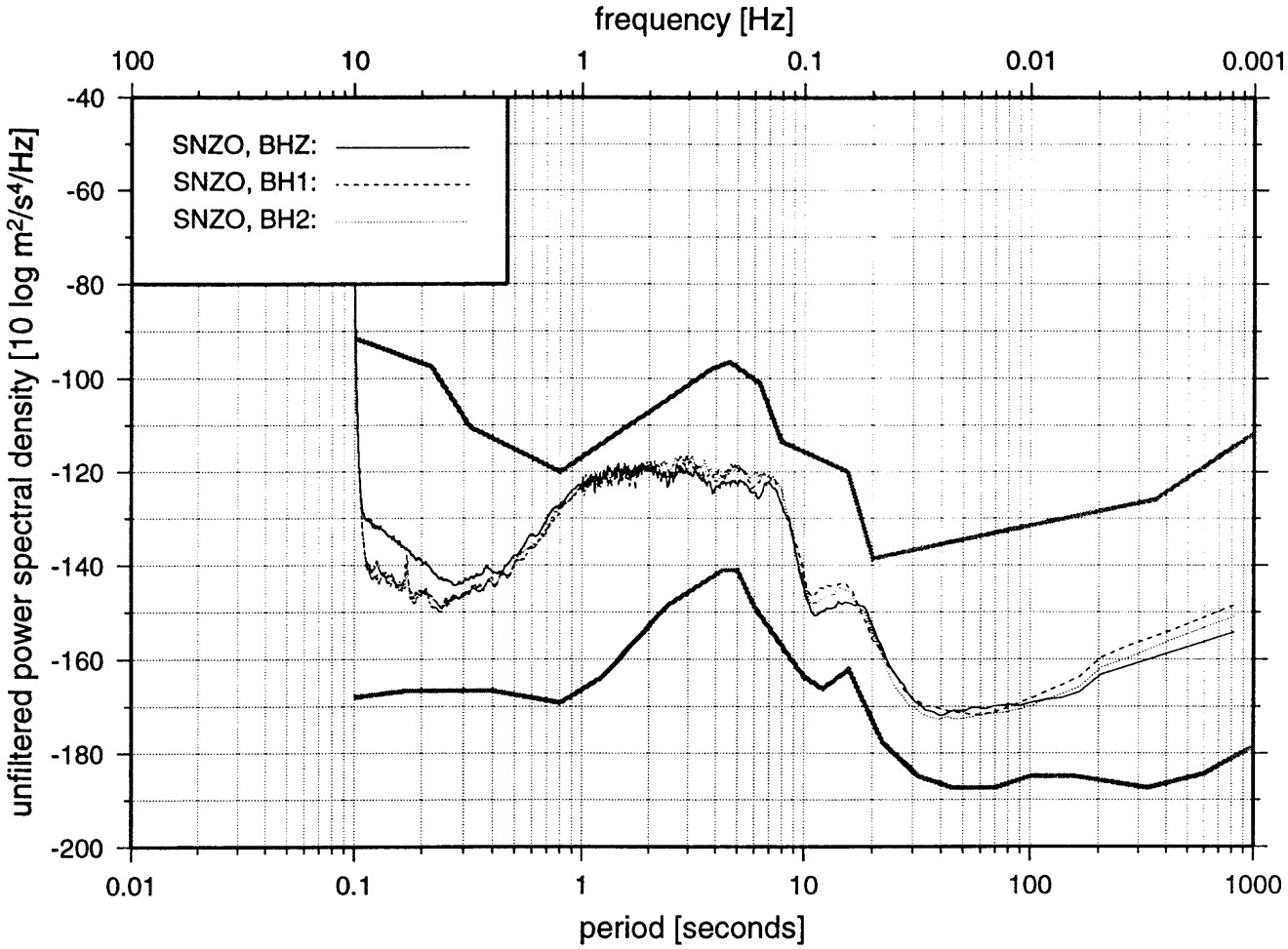


0. start time: 1998,117,05:17:47.398 length: 1.5 hours (demean) (lp co 0.0500 n 4) 5465.

GFS file: tele.gfs
min and max (<ret> for auto-scale) : -2400 2400
GFS file: tele.gfs

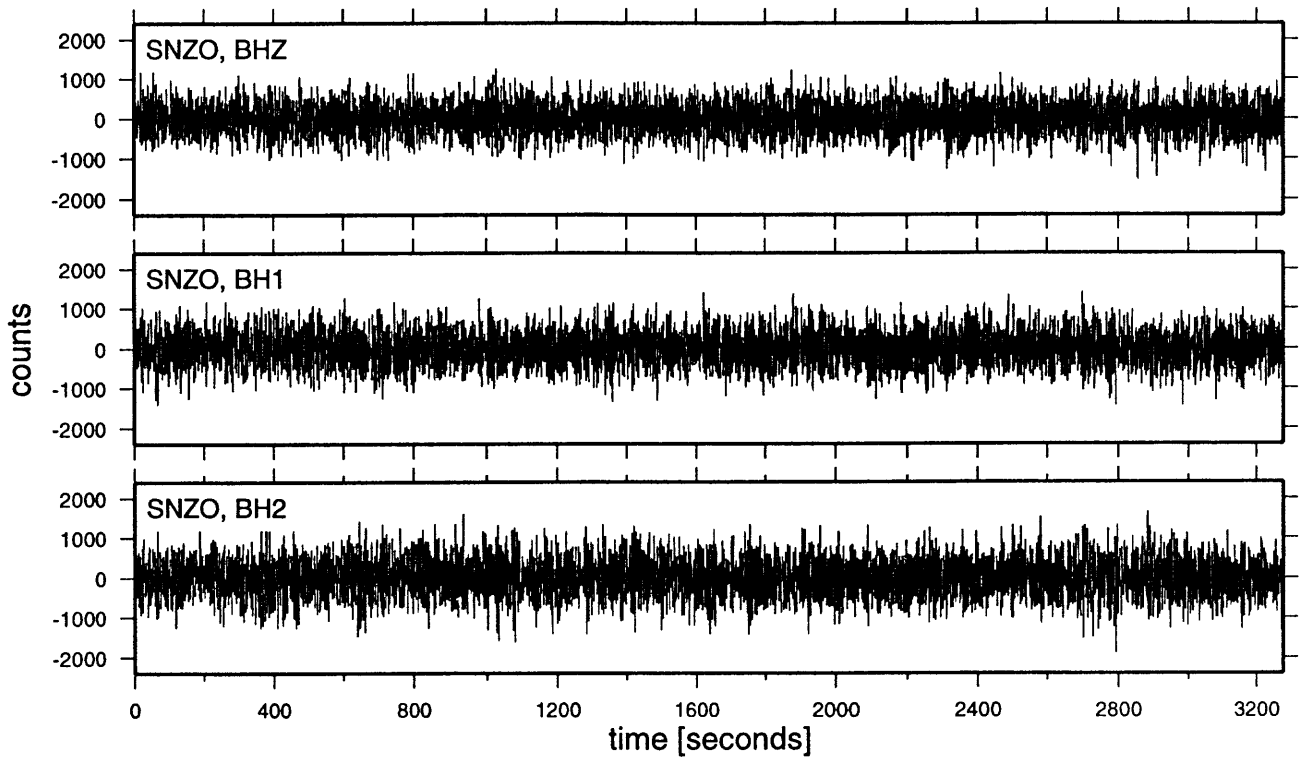
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

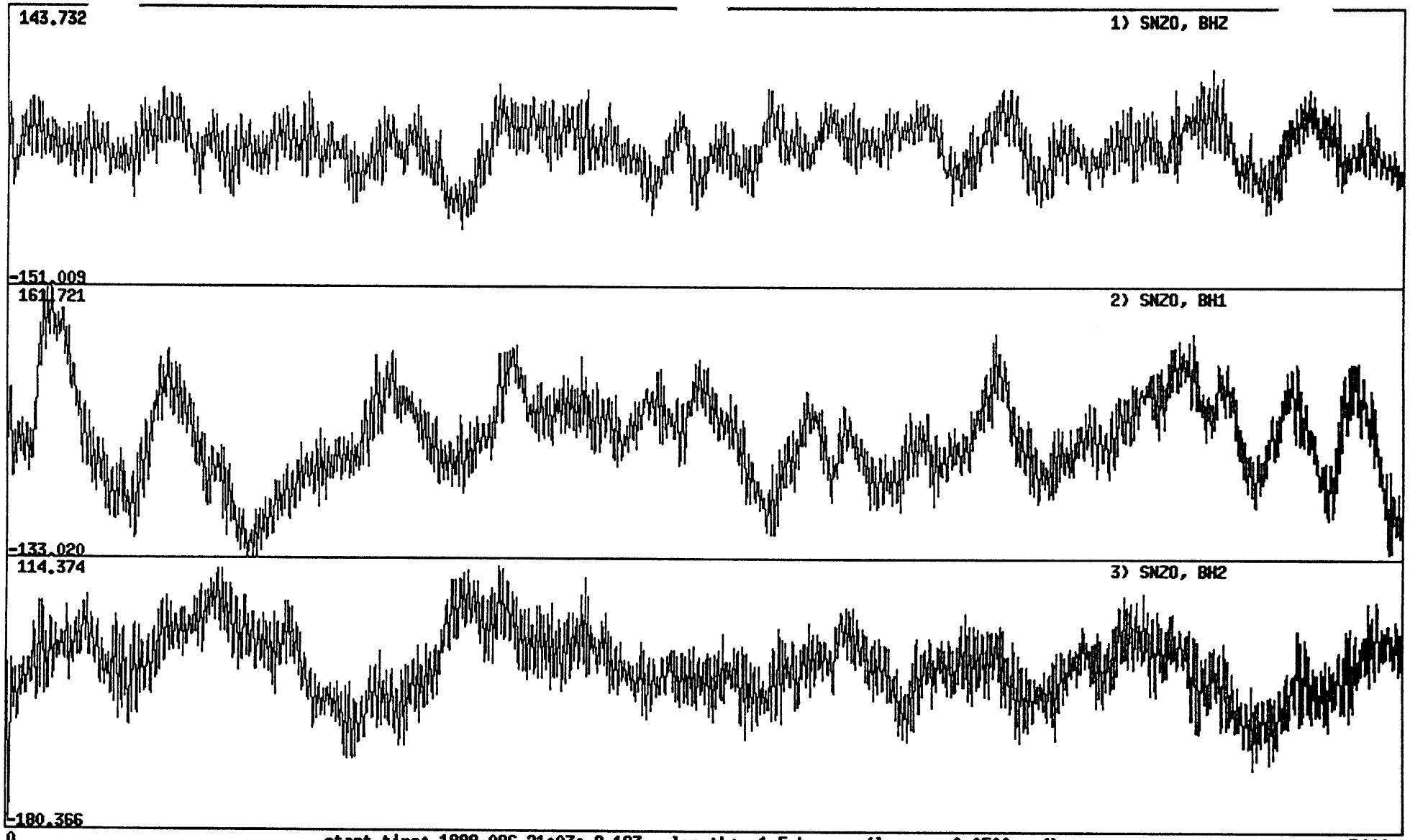
Seismic Spectra and Waveform Plot



WITH SAND

Start time **1998,117,04:57:18.136**

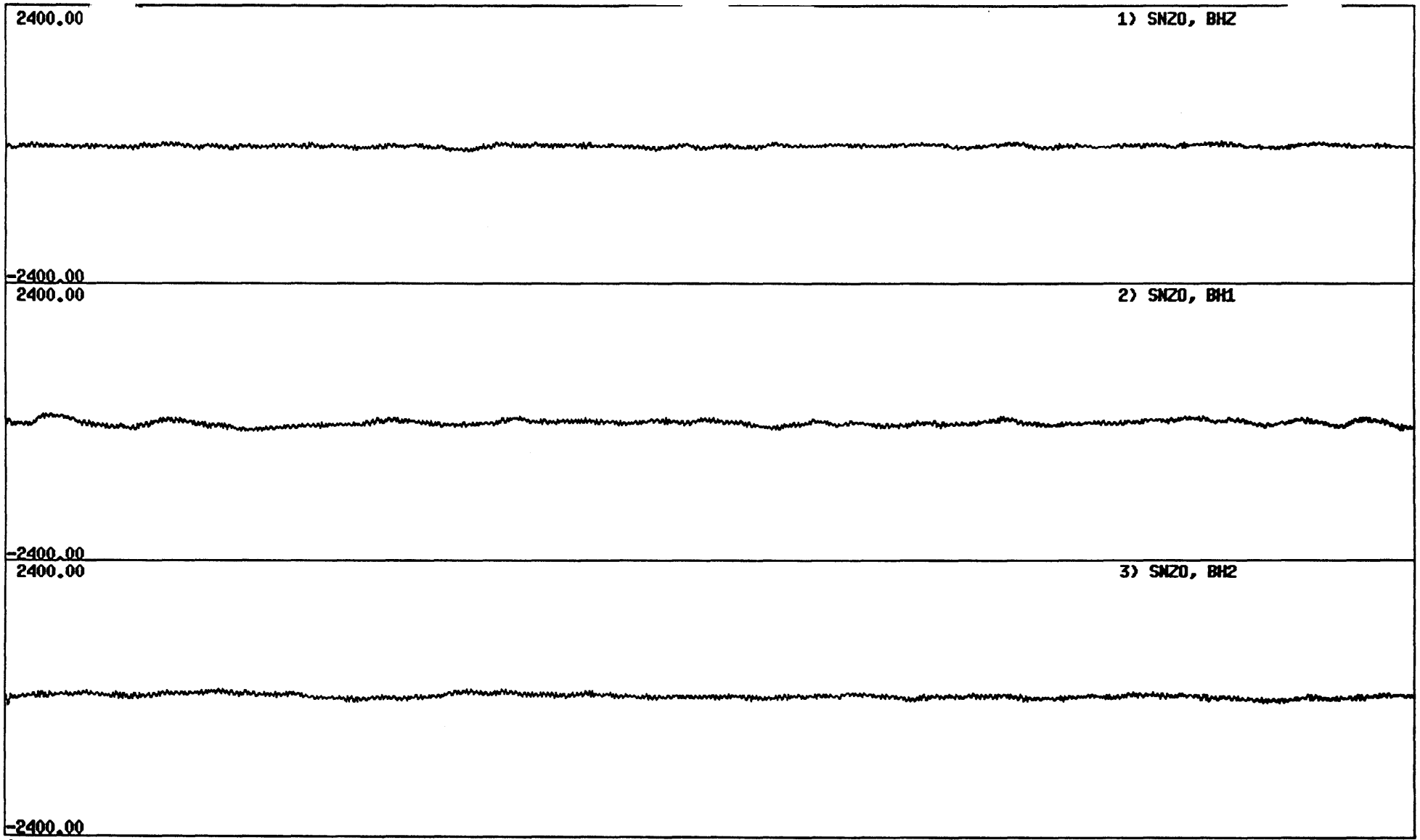




station: SNZO channels: BH1 BH2 BHZ
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

With Sand

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim



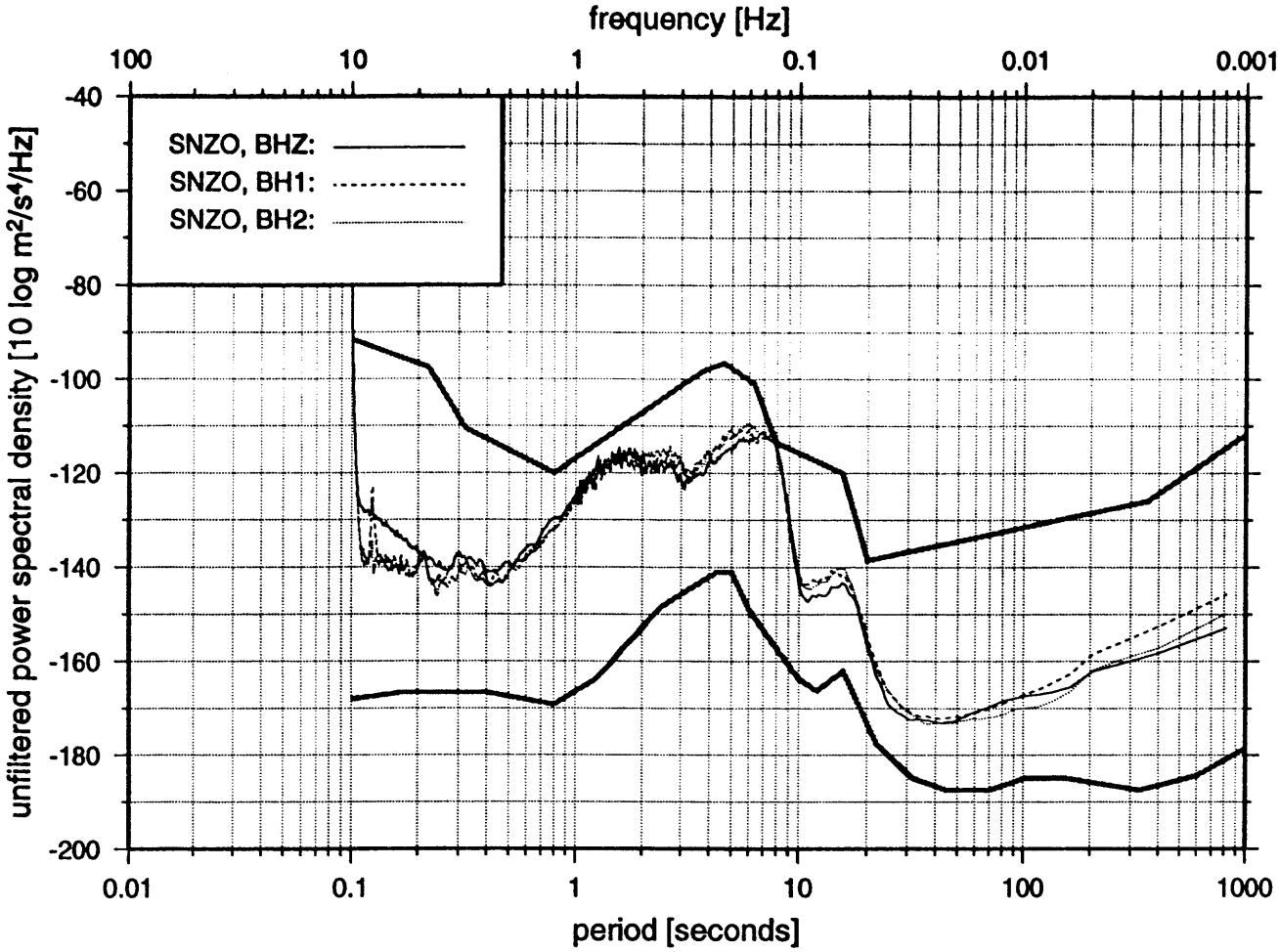
0. start time: 1998,096,21:03: 8.183 length: 1.5 hours (lp co 0.0500 n 4) 5444.

GFS file: tele.gfs
min and max (<ret> for auto-scale) : -2400 2400
GFS file: tele.gfs

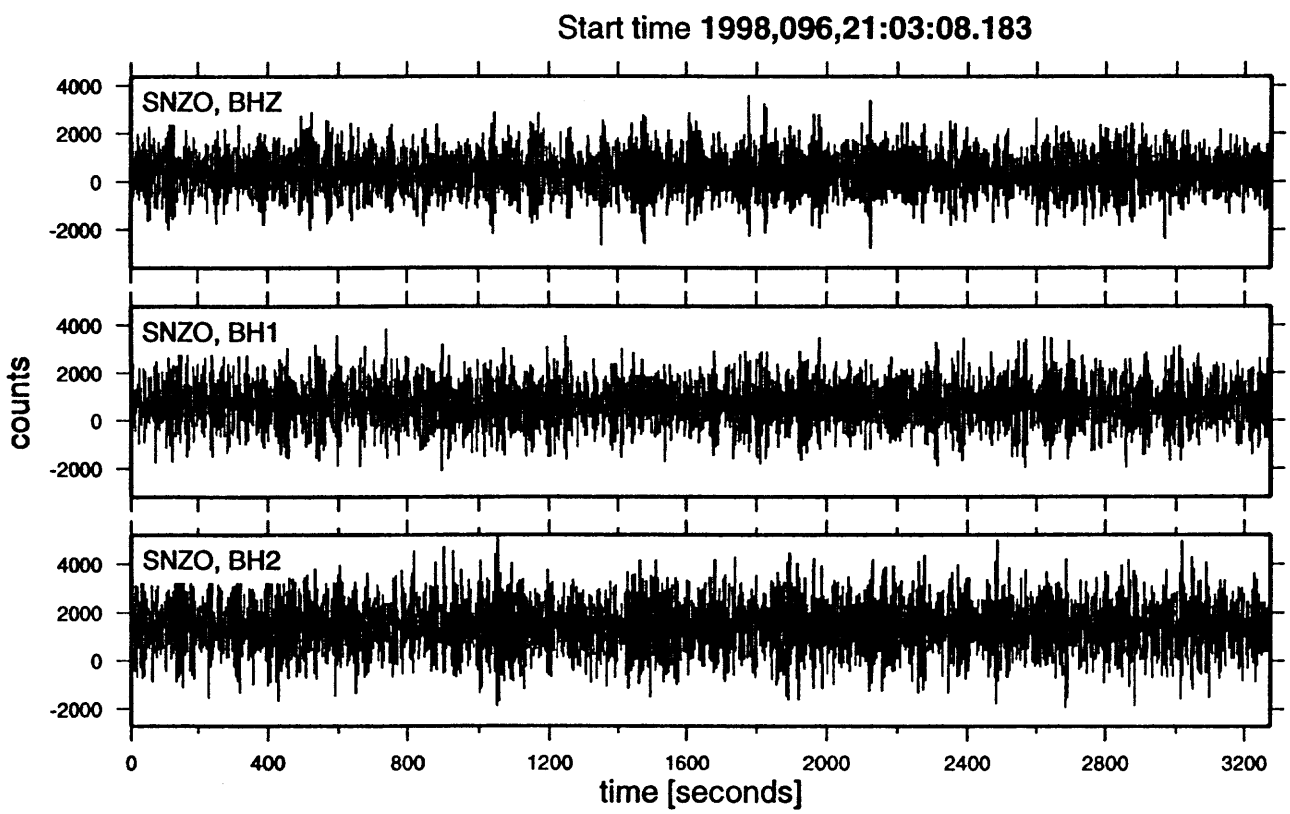
With Sand

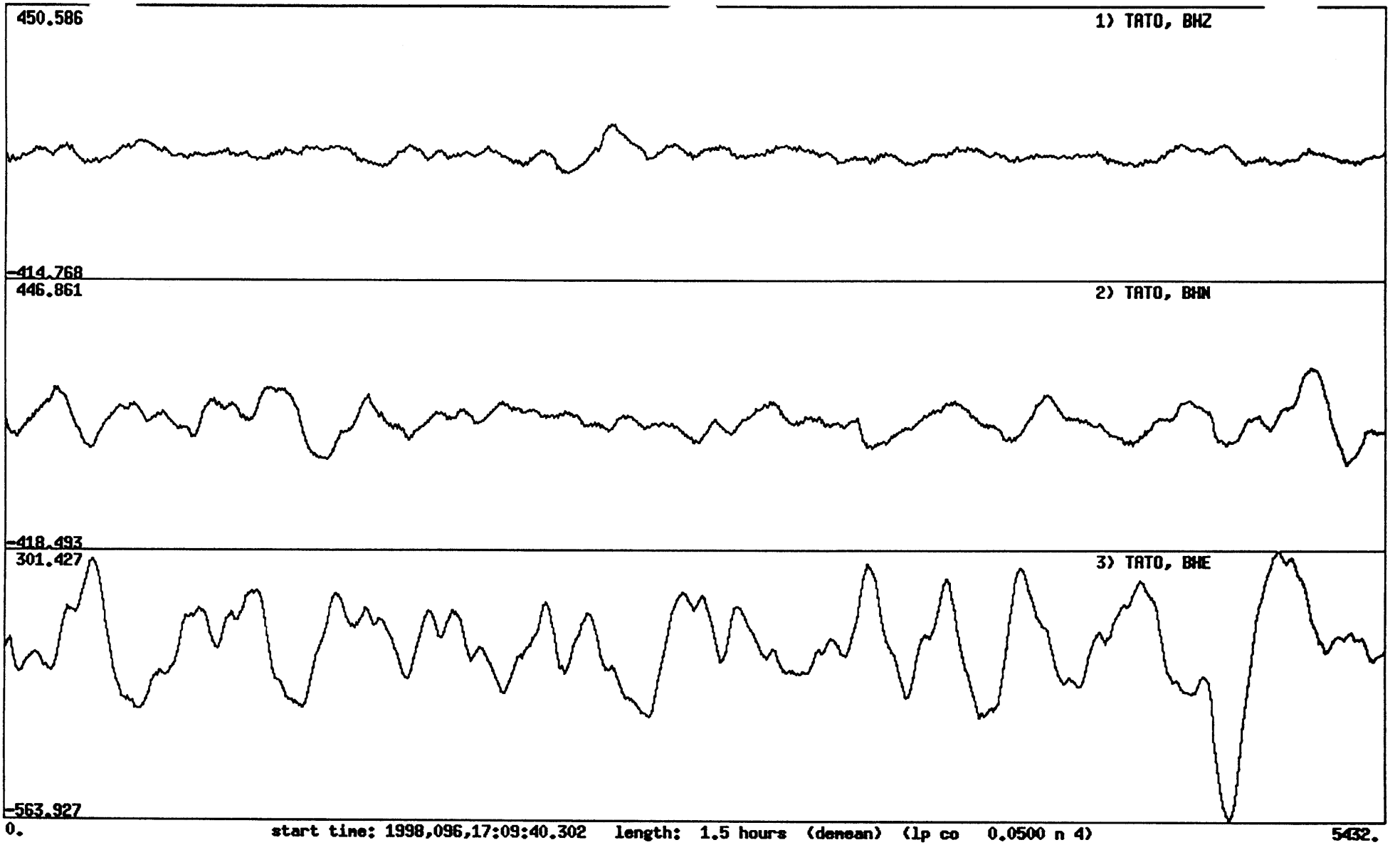
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlin B) ylin

Seismic Spectra and Waveform Plot



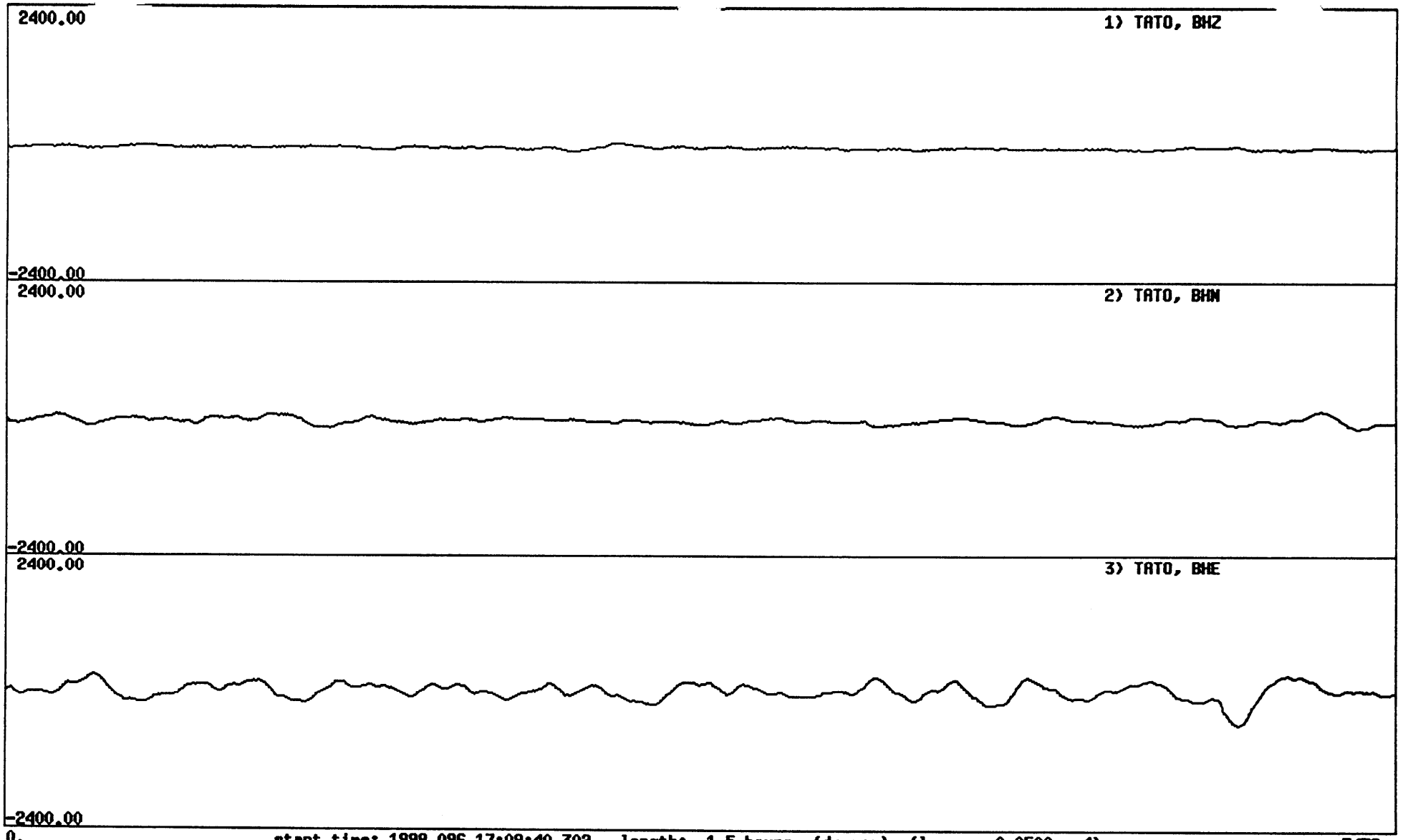
With Sand





station: TATO channels: BHE BHN BHZ
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

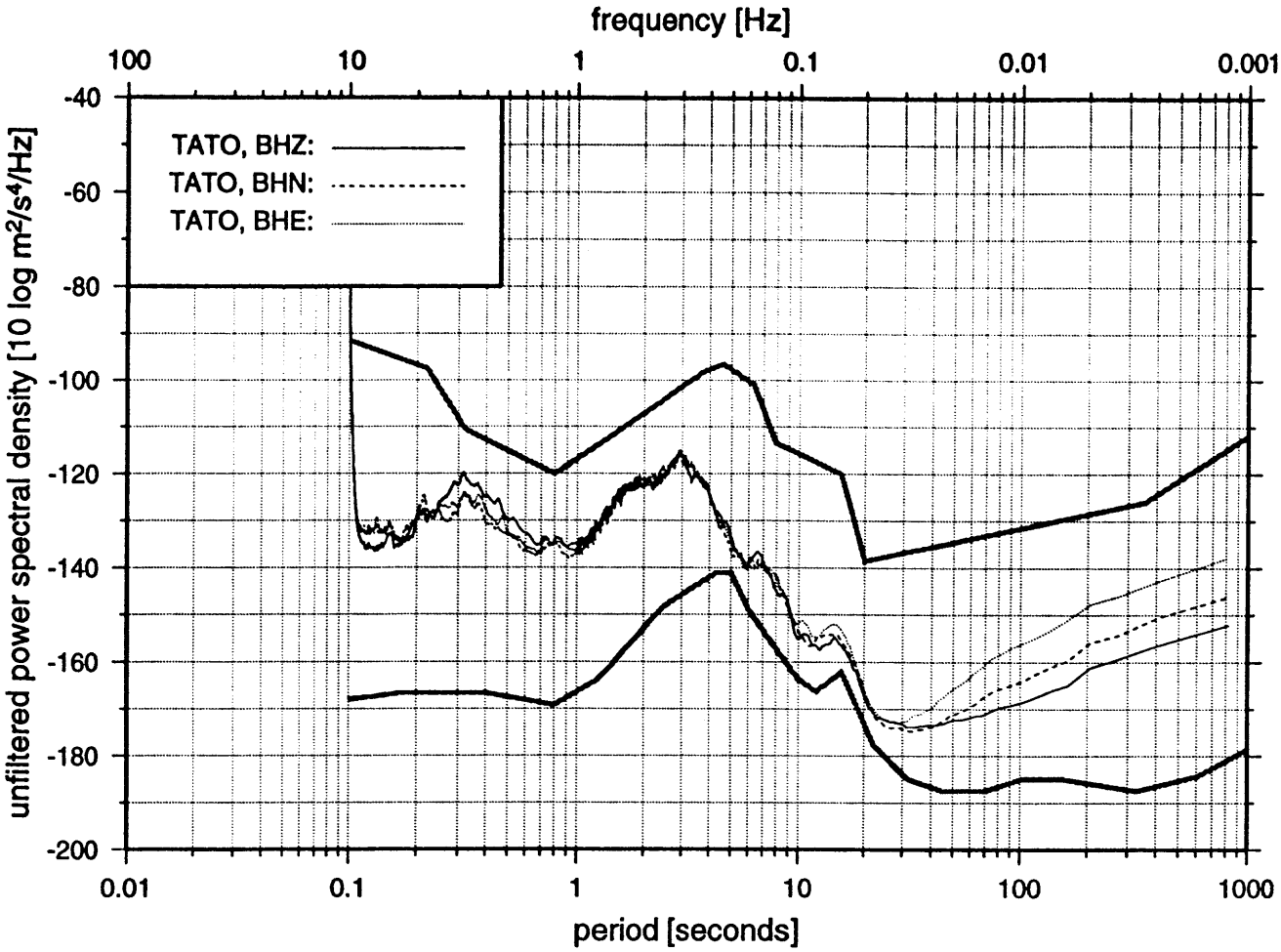
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

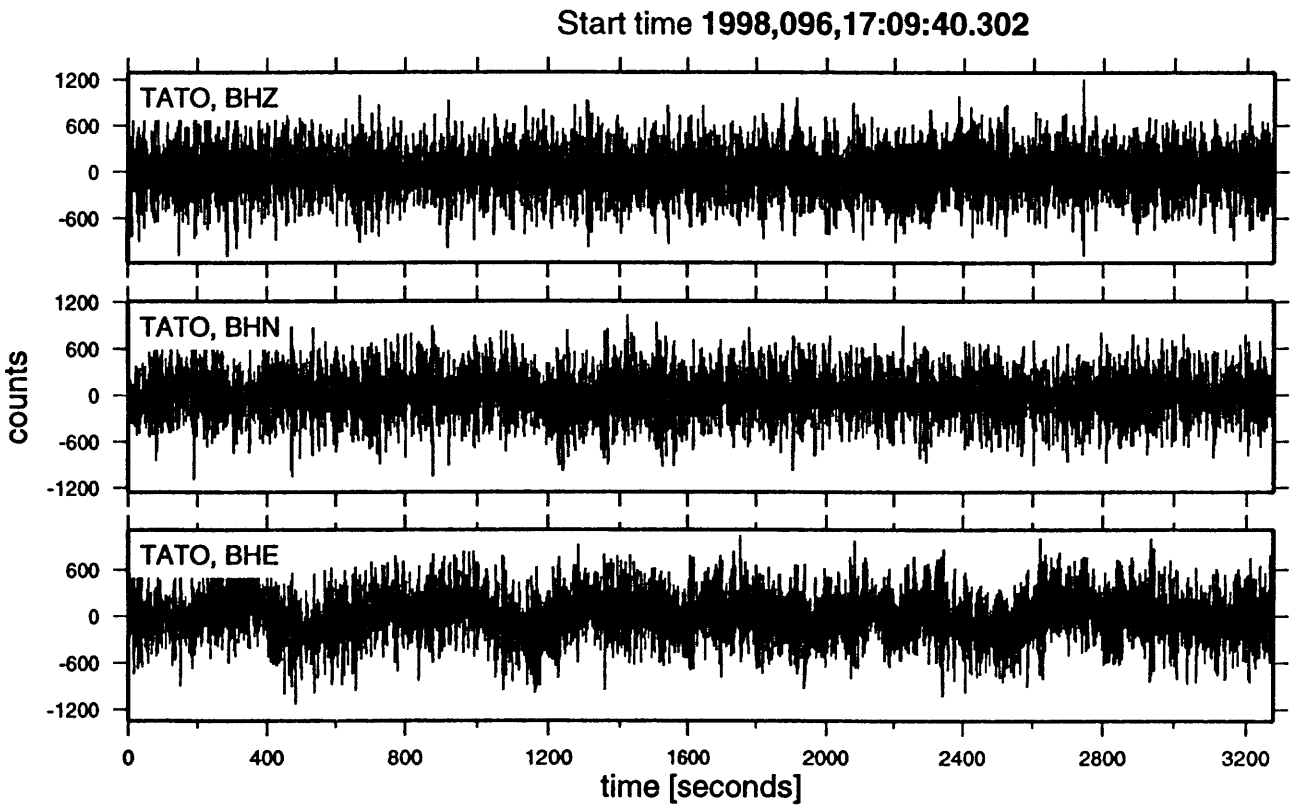


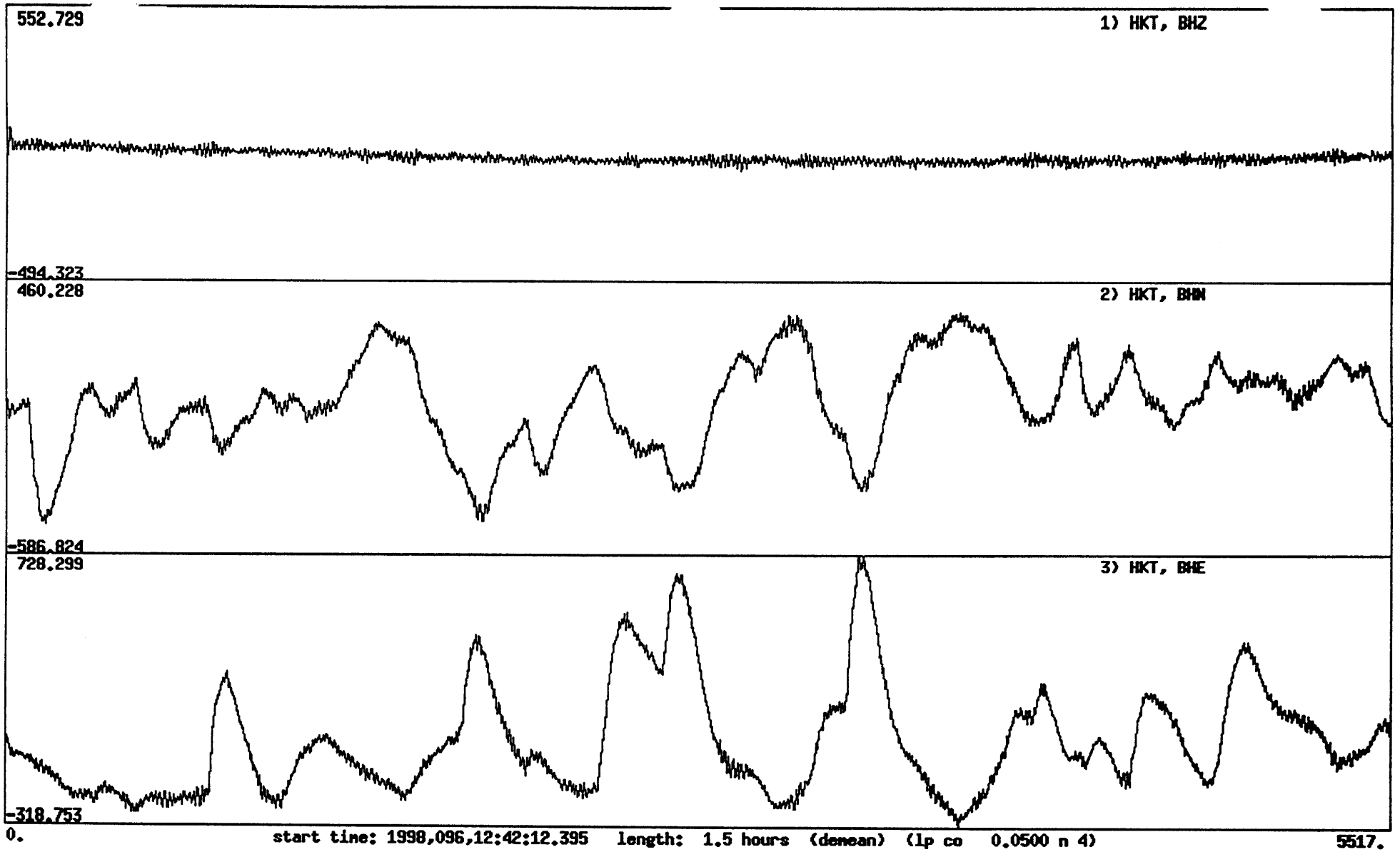
GFS file: tele.gfs
min and max (<ret> for auto-scale) : -2400 2400
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

Seismic Spectra and Waveform Plot

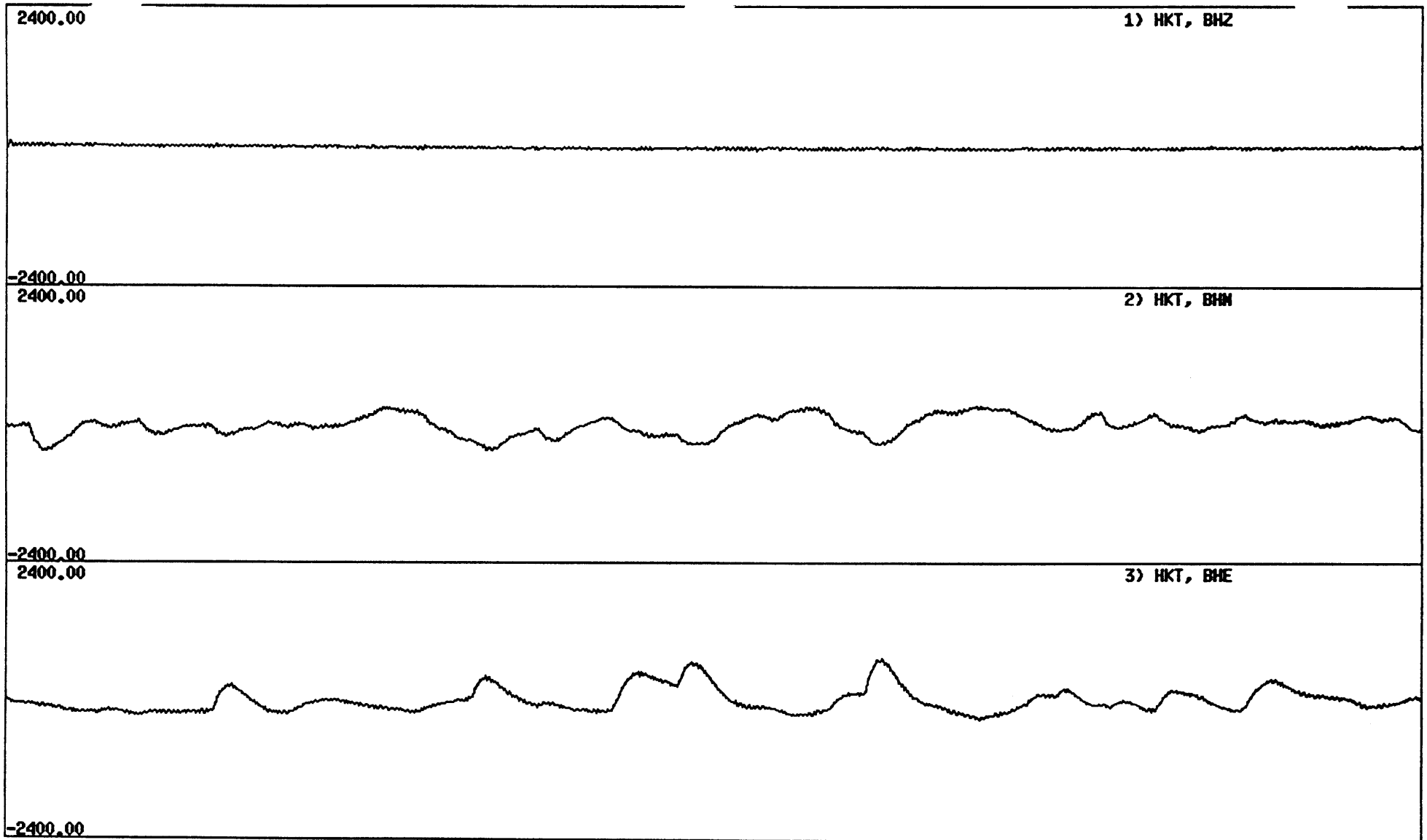






invalid range - try again
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

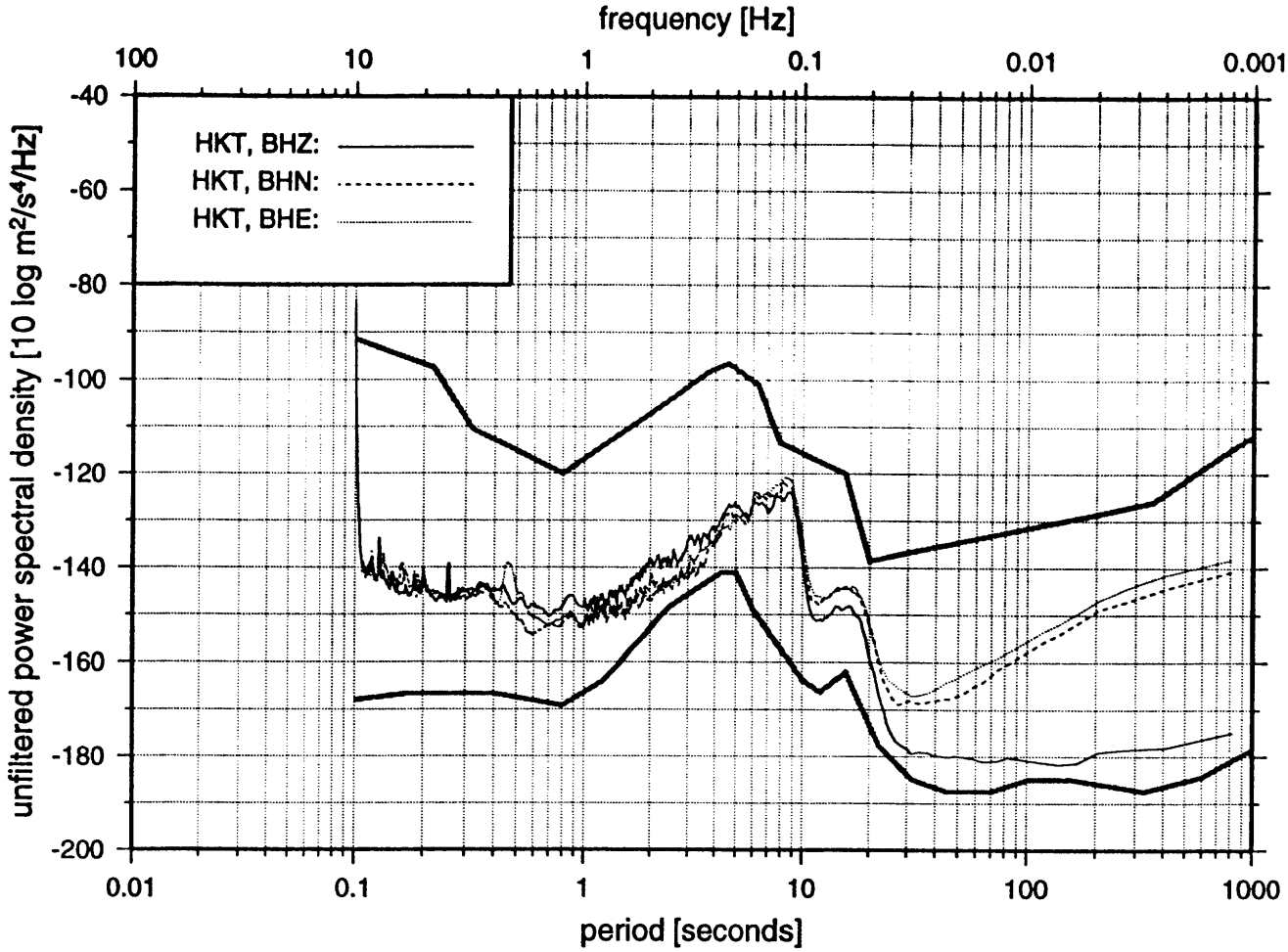
PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) con C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

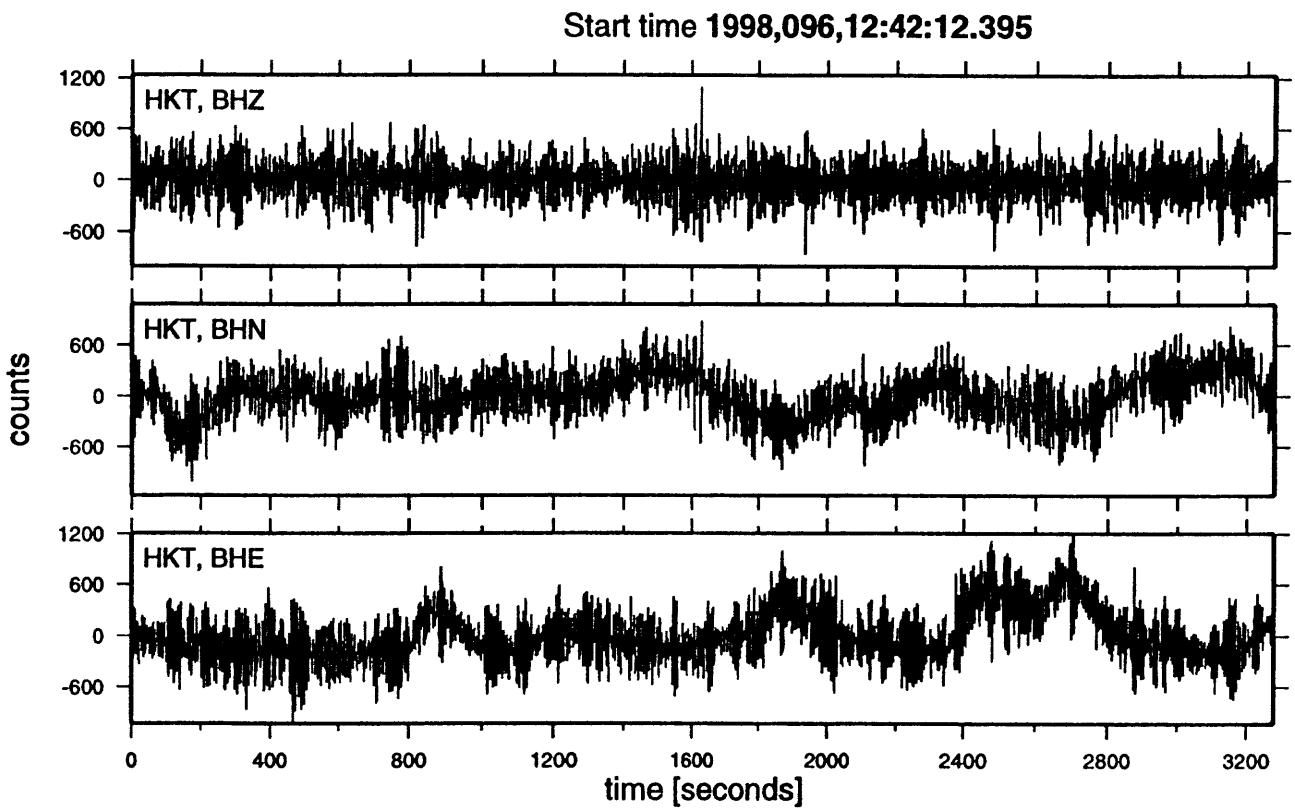


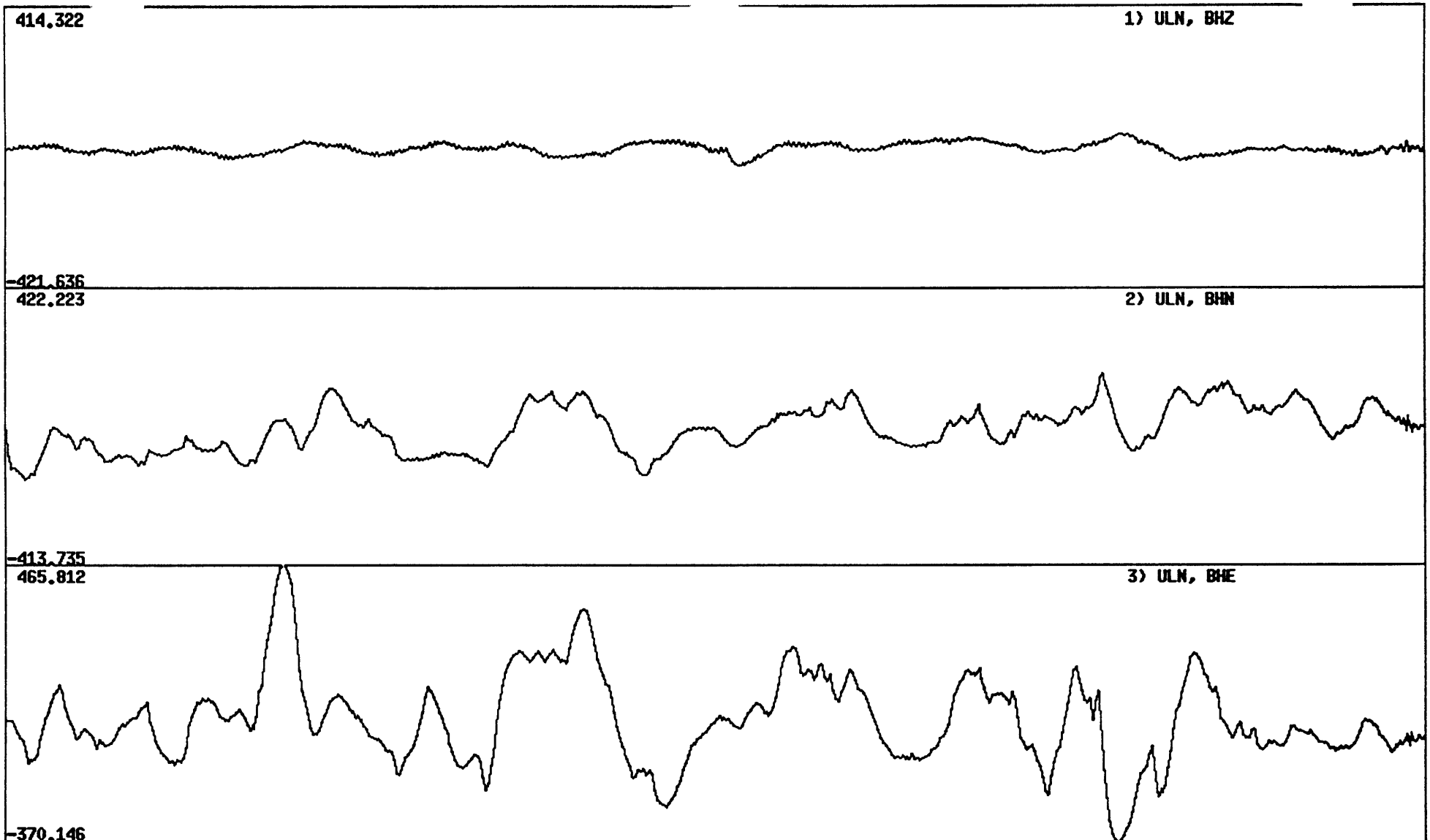
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
min and max (<ret> for auto-scale) : -2400 2400
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

Seismic Spectra and Waveform Plot

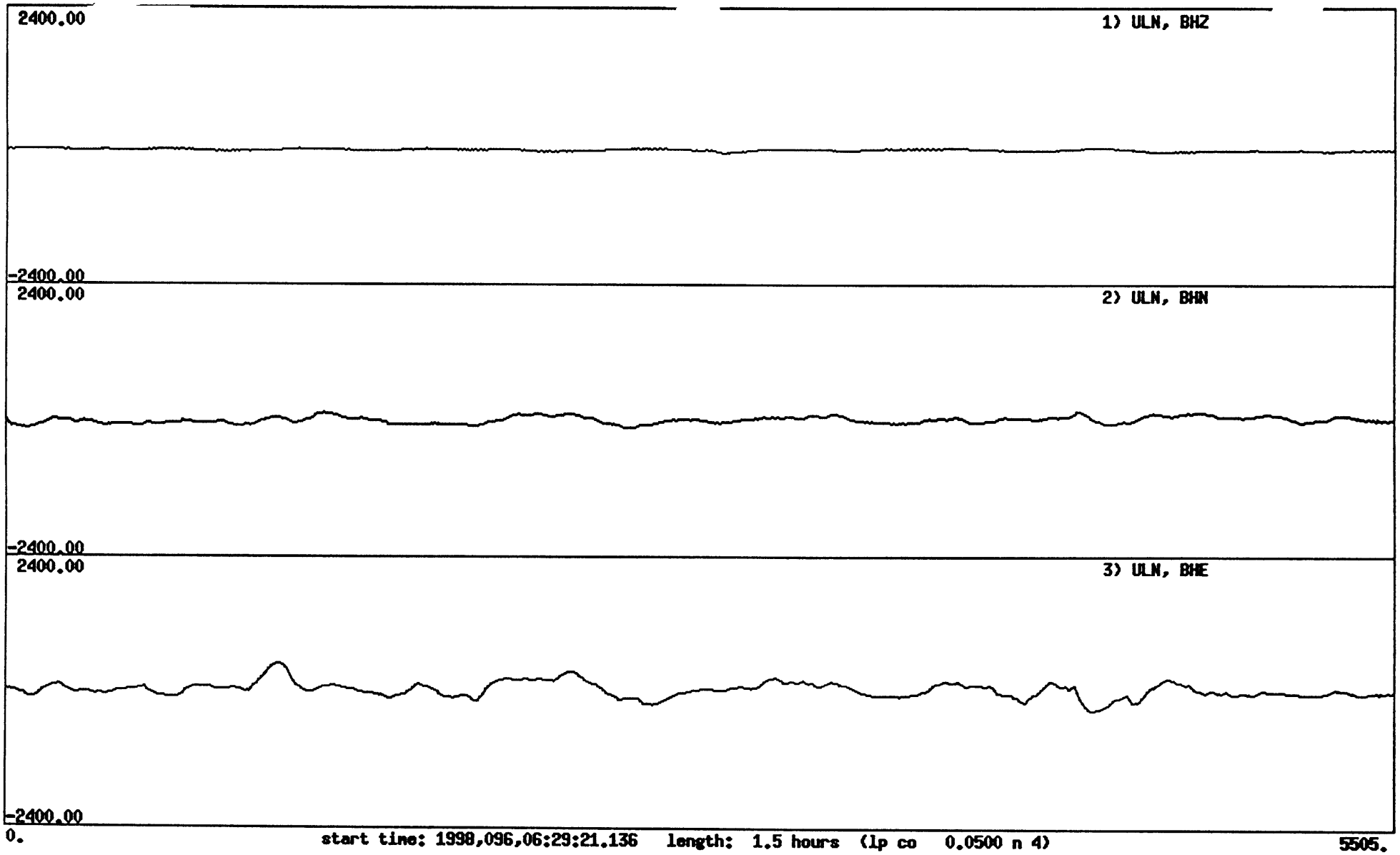




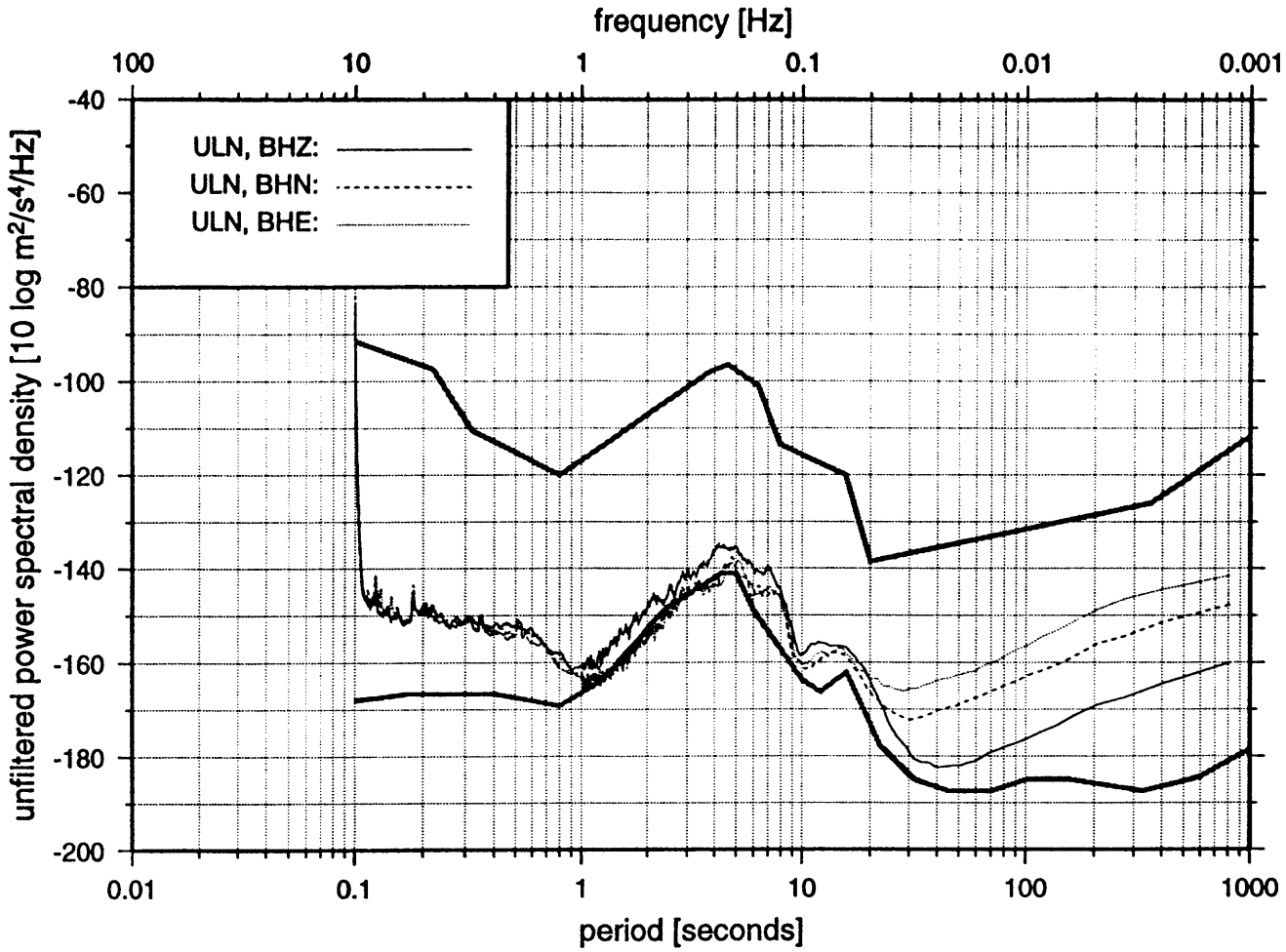
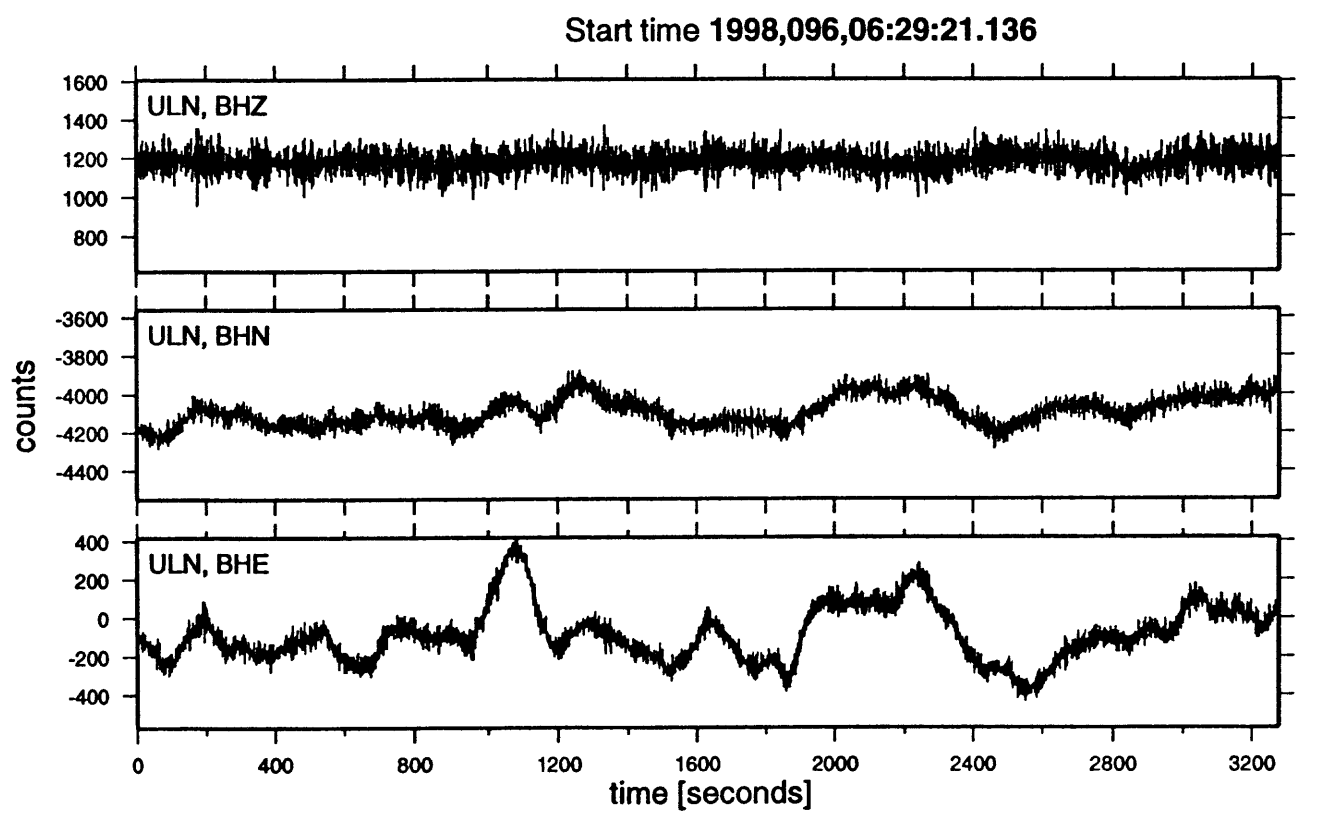


station: ULN channels: BHE BHN BHZ
filter options (1=lp, 2=hp, 3=bp): 1 .05 4
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim



GFS file: tele.gfs
min and max (<ret> for auto-scale) : -2400 2400
GFS file: tele.gfs

PLT: A) plot B) sel C) ovr	DMP: A) SAC B) GFS C) ASCII	hardcopy	SCL: A) auto B) com C) xhair
A) next+plot B) next C) back	quit	A) offset B) ttpick C) delpick	A) PPM B) PSD C) RESP
TOG: A) phases B) color C) mean	PHS: A) + B) - C) EQ ID	FLTR: A) lp B) bp C) dyo	LIM: A) xlim B) ylim

Seismic Spectra and Waveform Plot