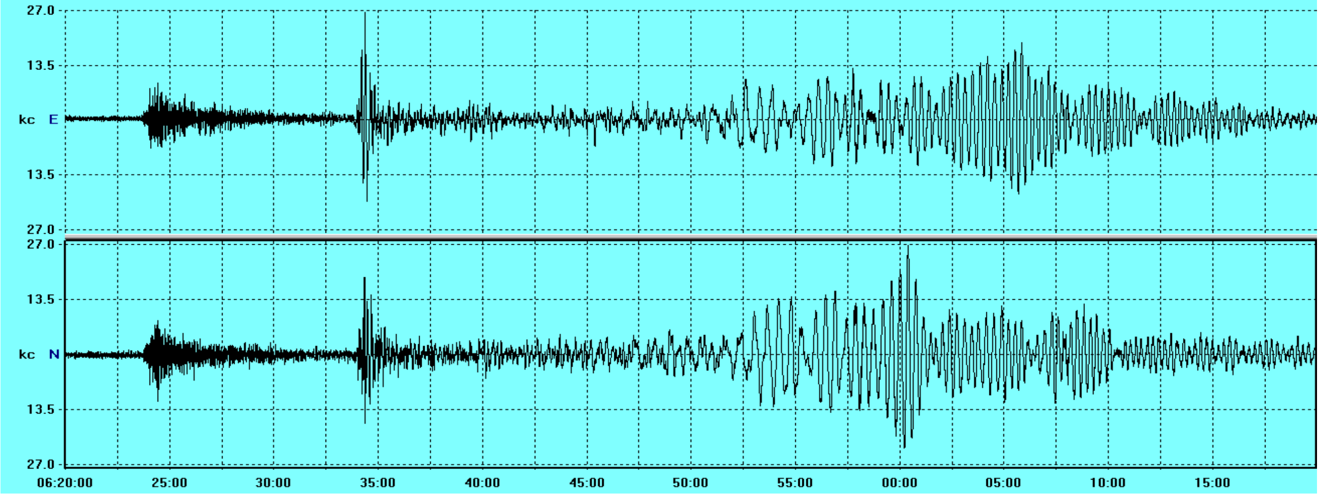
Response of

VolksMeter Seismograph

Hindmarsh Valley South Australia (TPSO)

35.489S 138.637E



Part 1:

To the Nepal M7.8 earthquake of 25th April 2015 06:11:26.

And for comparison, also showing the response of various other seismographs from the South Australian network.

Part 2:

To Earth tides from 17th April to 4th June 2015.

And for, comparison also showing the response of the Grotta Gigante seismograph at Trieste, Italy.

Paul G. Hutchinson **Director TPSO.**

Randall D. Peters PhD. **Emeritus Professor of Physics**

15th June 2015.

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Brief history of pendulum research and the recent commercial development of the fully digital pendulous horizontal VolksMeter **DISPLACEMENT** seismograph.

Examination of the inherent limitation of “coil-magnet” **VELOCITY** type seismographs which have (below their corner frequency) a 20 dB per decade decrease in output response to longer period Earth motions.

As compared to **DISPLACEMENT** type seismographs whose output response to longer period Earth motions remains directly proportional right down to DC or permanent TILT.

Comparison of various seismic waves emanating from the Nepal M7.8 earthquake of 2015-04-25 06:11:26 showing that the response of the horizontal VolksMeter **DISPLACEMENT** seismograph located at Hindmarsh Valley South Australia (TPSO) [35.489S 138.637E] compared favourably with the response of various horizontal **VELOCITY** seismographs located within the South Australian network.

Part 2. Earth Tides.

During the recording period 17th April 2015 through to 4th June 2015 the horizontal VolksMeter **Displacement** seismograph is shown to be especially sensitive to the 12 hour (semidiurnal) and 24 hour (diurnal) components. Autocorrelation plots of bandpassed records also show the occurrence of the minimum tidal field, when the Moon and Sun are at quadrature (90 degrees apart). These occur 7.38 days after a new Moon or a full Moon.

As confirmed by comparison with the horizontal Grotta Gigante **Displacement** seismograph located at Trieste, Italy [45.708 N 13.763E] which competently records yearly and decade long Earth tides.

Further research is planned by placement of a Streckeisen STS-2 **Velocity** seismometer upon the pier of TPSO so allowing for the proven excellence of the STS-2 with its [higher] optimal frequency performance regime to be directly compared with the [lower] optimal frequency performance regime of the VolksMeter **Displacement** seismometer. The synergetic data from this pair of instruments upon the same pier particularly the complementary “frequency cross-over” regime of both instruments will be used [for the first time] to advance a variety of geosciences by improved measurements of acceleration/tilt with periods exceeding 1,000 seconds.

Hopefully giving new insights and a better understanding into the granular physics/dynamics that influence our planet before earthquakes.

Part 1. History, examination and comparison of VolksMeter.

1.1. History

The nearly-incessant free oscillations of the Earth (not the larger, long-lived normal modes seen following intense quakes) were first observed by accident (early 1990's) by Kwon and Peters in the record of a tilt-sensitive instrument located at Texas Tech University, designed to study surface physics.

R. Peters and M. Kwon were the first to see free earth oscillations that occur on a regular basis, and which are thought to be excited by relaxations of the anelastic earth under the influence of tidal strain.

> M. H. Kwon & R. Peters, "The study of eigenmode types and source nonlinearity in the free earth oscillations" Saemulli Vol. 35 no. 4, 569 (1995).

A decade later, following the application of well-known pendulum theory, and the invention and patenting of high resolution SDC sensors, Peters created (with expert assistance from business partners Larry Cochrane (electronics) and Les Lazar (mechanical components)-- the first fully digital seismograph called the VolksMeter.

Prior to the instrument's introduction to the commercial world, Peters gained valuable geophysics experience while working with NASA Jet Propulsion Laboratory scientist James H. Shirley. (online ref. https://science.jpl.nasa.gov/people/Shirley/)

After finding online the many Peters scholarly articles dealing with pendulums (largely open source publications, such as on arxiv) Shirley requested of Peters that a unique research project be undertaken by the two of them. The uniqueness of their endeavour involved only the electronics and computing power made possible by the modern age—since the first efforts to address the focus of the study they undertook, happened about a century before then. The historic efforts began with the celebrated physicist Lord Kelvin (1824 – 1907) and his understudy George Darwin (son of the famous evolutionist, Charles). It began with a simple pendulum, hanging from a doorframe on the ground floor of the physics building at Glasgow University. Kelvin and Darwin began a remarkably careful effort to master a problem that remains largely unsolved to this day; i.e. the complete understanding of the Moon's gravitational influence on the Earth. The sensing of pendulum motion method which they used (classic optical lever) is likely to be viewed by many nowadays as primitive. Nevertheless it allowed them to expose to the world for the first time some of the complexities of the Earth/Moon/Sun gravitational interaction. The best known feature of this complicated system— the tidal force—was first treated by Isaac Newton (1643 – 1727).

To the present day, there are still features of this important three-body- problem that have been far from adequately treated. Even the tidal force is prone to over-simplification, by ignoring what can be important asymmetry—treated by Peters in the article "Tidal force asymmetry", online at http://physics.mercer.edu/hpage/tidal%20asymmetry/asymmetry.html)

It was hoped that Shirley/Peters could by means of modern computing power (and more user friendly sensing than was present in the early 1900's) address one feature that Shirley hypothesized as being potentially significant. In particular Shirley believed that the Moon's 'whipping' of the Earth in a path of epicycle type –would result in a previously ignored, non-negligible 'inertial' force. (It is worth noting that the term 'inertial force', as used in physics, is a fictitious force that acts on all masses whose motion

1.1 History (Cont).

is described using a non-inertial frame of reference, such as a rotating reference frame. The best known example is the Coriolis force.)

Alas, even as the team of Kelvin/Darwin could not unravel all the mysteries of the Moon's influence, neither could Shirley/Peters.

But Peters was able with simplified analyses (using an unrealistic lunar orbit) to convince himself that Shirley's hypothesize should not be summarily rejected. Peters' conclusion was reached after data collection for several months, using a research grade pendulum that he created. The instrument is described online in the article,

"*Modernized conventional Pendulum Seismograph*" http://physics.mercer.edu/hpage/rpend.html

During this time the Banda Aceh earthquake occurred (26 Dec 2004). Not only was the event detected by this pendulum, but the instrument also responded clearly to the free oscillations of the Earth that followed.

The simplicity of the instrument, with a view toward creating a low-cost but effective seismograph—resulted in Mercer University generating a news release about Peters' pendulum. This news release was picked up by the German Magazine Der Spiegel, where the editor referred to its potential as a Volks Seismograph – "Seismograph for the people". Thus was the genesis of the VolksMeter, which was also described in Popular Science (April 2005). The Popular Science article resulted in a contact between Peters and Les Lazar, and shortly thereafter, the two of them with Larry Cochran. Cochrane had already before that been working with the AD7745/6 chips produced by Analog Devices. It is the heart of the electronics, used in conjunction with the array-form SDC sensor of the **VolksMeter**.

1.2. Introducing the VolksMeter.

Presentation as made by Randall D. Peters, PhD Professor & Chairman Department of Physics, Mercer University, Macon, Georgia, USA to the American Geophysical Union December 2006 meeting when he introduced the **VolksMeter.**

> *"Years ago the electronics of conventional seismographs became largely digital; however, their primary sensor components have remained analog. The **Volksmeter** is the first bona fide fully-digital seismograph. It is a conventional pendulum (horizontal) instrument that uses the award-winning integrated circuit (AD7745) from Analog Devices, that is a capacitance to digital converter (CDC). To measure pendulum motion, this chip monitors a symmetric differential capacitive (SDC) displacement sensor array -- one form of the first fully differential capacitive sensor. The SDC-CDC package is configured to operate in a different mode than conventional seismographs. By recording pendulum position, rather than velocity, tilt response of the **Volksmeter** opens a new window to the world of inexpensive instrumentation. It provides a simple means to study really-low frequency spectral components of oscillatory type, called `earth hum.' Examples of benefit from these novel features will be provided, along with some history of the **Volksmeter** evolution from a fundamental research program.**"***

http://adsabs.harvard.edu/abs/2006AGUFM.S14B..01P

1.3. Benefits of the VolksMeter.

Details of how the **VolksMeter** evolved from fundamental physics research and the benefits of,

- Symmetric Differential Capacitive (SDC) sensor operating on the basis of area-variation, rather than gap-spacing. US patent No. 5,461,319 held by Peters.
- Analog Devices capacitance to digital converter (CDC) AD7745.
- Simple easy unambiguous instrument calibration - e.g. 3.06 Counts per nanoradian.
- Flat response from 1 Hz to DC [Permanent TILT].
- Instrument self noise of -130 dB (re m^2/s^3 per one-7th decade) at 0.000023Hz (23 µHz or 12 hours period) being substantially better than any of the best velocity detectors at or below this frequency.
- Resolution 0.4 nanoradian (0.1 nanometer displacement of sensor moving electrode).
- Easily generate TRUE power spectral densities (PSD's) [Watts per Kg per one-seventh decade.]

These and others of the benefits of the horizontal **VolksMeter Displacement** seismometer**,** as were presented by Peters to the American Geophysical Union December 2006 meeting are to be found at, http://www.seismicnet.com/volksmeter/State-of-the-art_Digital_Seismograph.pdf

VolksMeter manufactured by **RLL** Instruments Inc. of Van Nuys California.
http://www.rllinstruments.com/

Professor Randall Peters' Curriculum Vitae is at http://physics.mercer.edu/hpage/vita.html

1.4. Comparison of responsiveness.

The Nepal M7.8 quake with seismic waves of different frequencies and different amplitudes passing through the South Australian network provides an opportunity to compare the basic responsiveness of a horizontal VolksMeter **Displacement** seismograph located at TPSO with the responsiveness of other horizontal **Velocity** seismographs within the South Australian network.

1.5. Horizontal seismographs used in this comparison.

- The Volksmeter located at Hindmarsh Valley at The Peters Seismological Observatory (TPSO)
- The Guralp 1 second short period instrument located at Mount Rat (MRAT)
- The Guralp 30 second long period instrument located at Mount Bonython (ADE)
- The Streckeisen STS-2 120 second Very BroadBand instrument located at Buckleboo (BBOO)

1.6. Horizontal seismographs compared against the following waves.

- Short Period P and S wave arrivals,
- Long Period Rayleigh Wave arrivals,
- Ground motion an hour and a half after initial P arrival – commencing 07:50:00,

1.7. Instrument Classification.

(As used here, <u>Displacement and Velocity</u> refer to state variables of motion, of the instrument's inertial mass, relative to instrument case)

VolksMeter 1 second short period	**Displacement** sensor
Guralp 1 second short period	**Velocity** sensor (i.e., time derivative of displacement)
Guralp 30 second long period	**Velocity** sensor
Streckeisen 120 second period	**Velocity** sensor.

As such **Part 1** being a basic comparison of horizontal seismographs against the various waves of the Nepal M7.8 quake is really about just how well does a **DISPLACEMENT** sensor compare to a **VELOCITY** sensor.

1.8. The two types of instruments.

1.8.1 Displacement instruments.

Having a **Displacement** sensor, the VolksMeter seismograph measures acceleration and/or tilt of the Earth, in the frequency range of its design focus.

For periodic motion of the Earth that is longer than its natural period of 1.09 seconds, the horizontal VolksMeter **Displacement** seismometer output is directly proportional to the horizontal components of ACCELERATION (or TILT) of the Earth.

Directly proportional even at very long periods out to DC. It can be shown theoretically that both acceleration and tilt (which are indistinguishable for a single instrument operating alone) cause VolksMeter response.

At short(er) periods of excitation, Earth acceleration dominates over tilt.

At long(est) periods of excitation, the tilt is dominant.

With the transition between acceleration and tilt taking place at several hundred seconds. Thus for most eigenmode oscillations the instrument responds to tilt when it is located at 'cardinal' points of latitude/longitude for a given free mode of the Earth. In the case of the tidal influence, there is a direct gravitational influence of the Moon and Sun (via Newton's universal gravitational inverse square-law) acting on the pendulums of the instrument.

(R. Peters, "Tutorial on gravitational pendulum theory applied to seismic sensing of translation and rotation", Bulletin of the Seismological Society of America, May 2009, vol 99 no 2B 1050-1063.

http://physics.mercer.edu/hpage/bssa-tutorial/pend-theory.pdf

For Earth motions having a period shorter than its natural period of 1.09 seconds the output from the VolksMeter **Displacement** seismometer decreases 20dB per decade in response to the accelerations of the Earth. So for ever decreasing period motions less than 1.09 seconds, the output is ever increasingly attenuated.

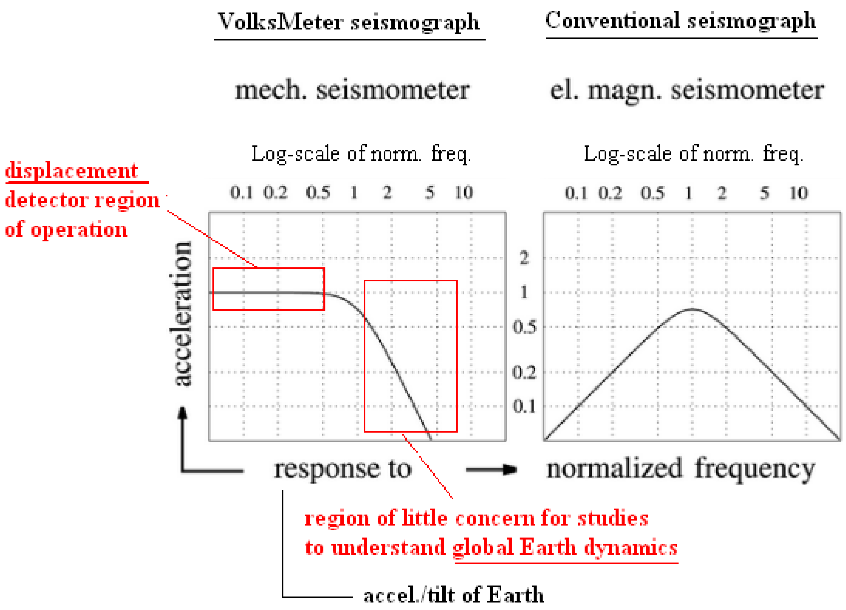
In addition, the VolksMeter **Displacement** seismometer has sampling rates selectable from 10 SPS up to 80 SPS.

The lower sampling rate of 10 SPS has been selected in order to reduce electronic noise; so bandwidth is limited to a maximum (Nyquist) frequency of 5 Hz, a period of a fifth of a second, which has no effect upon researching global Earth dynamics involving long period eigenmodes and Earth tides.

As the frequency decreases [period increases] for **Displacement** instruments below "corner" frequency, so the output remains directly proportional, as shown in the Erhard Wielandt frequency diagram below.

1.8. The two types of instruments (Cont).

1.8.1 Displacement instruments (Cont).



displacement detector region of operation

region of little concern for studies to understand global Earth dynamics

VolksMeter response is 'flat' to Earth acceleration at long periods

Conventional seismograph response is increasingly attenuated as period increases beyond the 'corner'

Every instrument responds directly to one thing only--acceleration of the 'Earth'

A seismograph responsive to ever-longer periods is better able to measure
Earth motions especially responsible for the generation of earthquakes

Fig. 1.8.1. “Flat” response of **Displacement** seismographs to acceleration/tilting being below corner frequency. Diagram adapted from Erhard Wielandt IASPEI Chapter 5.9.2.

1.8. The two types of instruments (Cont).

1.8.2 Velocity instruments.

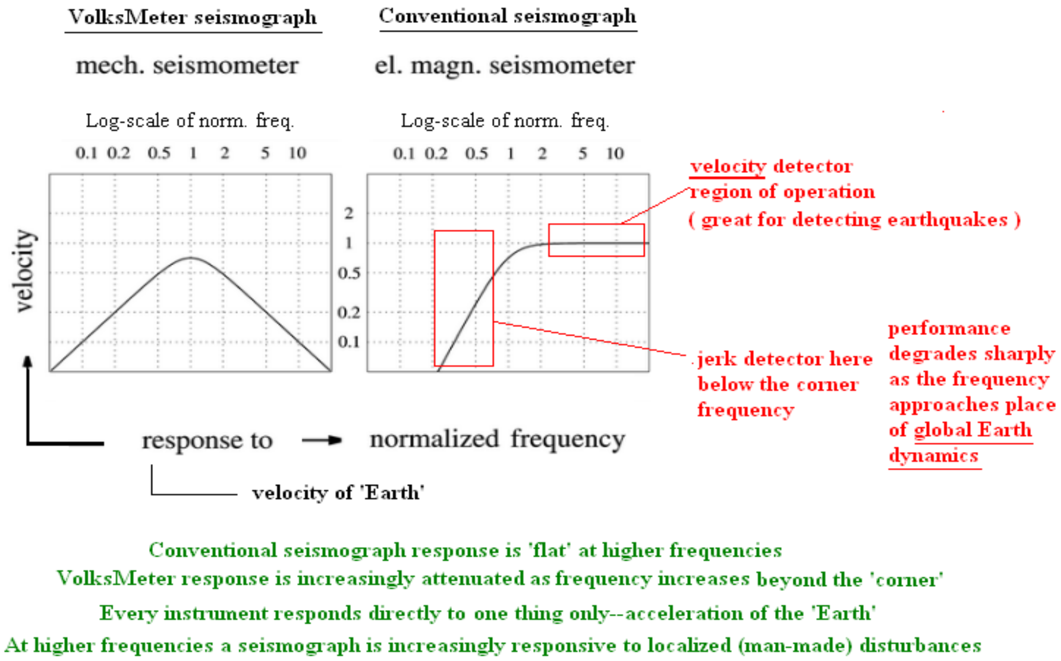
The Mount Rat (MRAT) One Second short period Guralp and the Adelaide (ADE) 30 Second long period Guralp and the Buckleboo (BBOO) Streckeisen STS-2 120 second Very BroadBand seismographs are all **Velocity instruments** measuring the "Time Rate of Change" (time derivative) of the displacement of the coil/Mass relative to the magnet/instrument case.

For periodic motion of the Earth having frequency greater than the corner frequency of the **Velocity instrument**, the output is directly proportional to the **Velocity** of these shorter period Earth motions. Making Velocity instruments ideally suited to detection of very short period earth motions.

But for all periodic motion of Earth in which the period (reciprocal of frequency) is longer than the corner period of the **Velocity instrument** there is a 20dB per decade decrease in output response to these increasingly longer periods of Earth motion. This is the intrinsic design limitation of all **Velocity** instruments, being that ever increasing periods of Earth motion, there is an ever increasing attenuation of output.

For **Velocity instruments** to detect the long period eigenmodes or the very long period Earth tides or ocean loading on the crust, they must have a long corner period like the Streckeisen STS-2's 120 second period. Such **Velocity instruments** must also be housed in extremely quiet thermally stable and geologically stable seismic vaults. The actual natural period of these **Velocity instruments** is generally shorter than the 'effective' corner period —by means of the electronics feedback circuitry that is employed by force balance instruments.

As the frequency decreases [period increases] for **Velocity** instruments below "corner" frequency, so the output is ever increasingly attenuated, as shown in the Erhard Wielandt frequency diagram below.



velocity detector region of operation (great for detecting earthquakes)

jerk detector here below the corner frequency

performance degrades sharply as the frequency approaches place of global Earth dynamics

Conventional seismograph response is 'flat' at higher frequencies

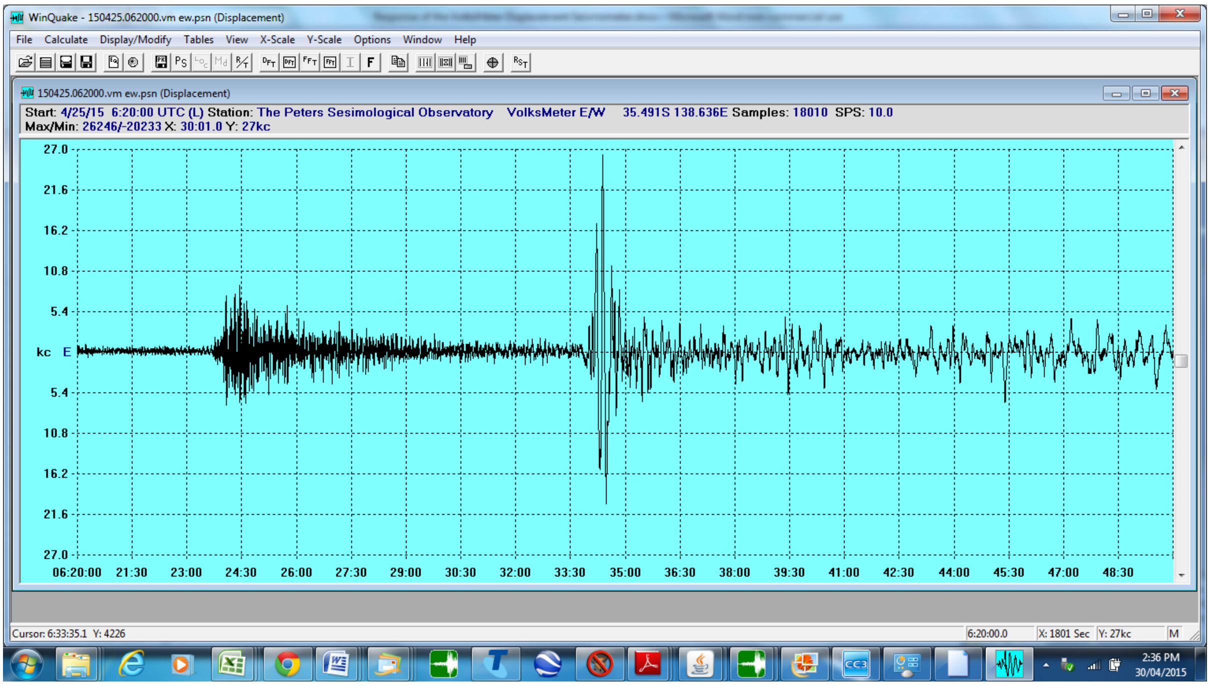
VolksMeter response is increasingly attenuated as frequency increases beyond the 'corner'

Every instrument responds directly to one thing only--acceleration of the 'Earth'

At higher frequencies a seismograph is increasingly responsive to localized (man-made) disturbances

Fig. 1.8.2. "Falling away" response of **Velocity** seismographs to earth accelerations being below corner frequency. Diagram adapted from Erhard Wielandt IASPEI Chapter 5.9.2.

1.9. Comparison of the responsiveness of the four seismographs to Short Period waves.



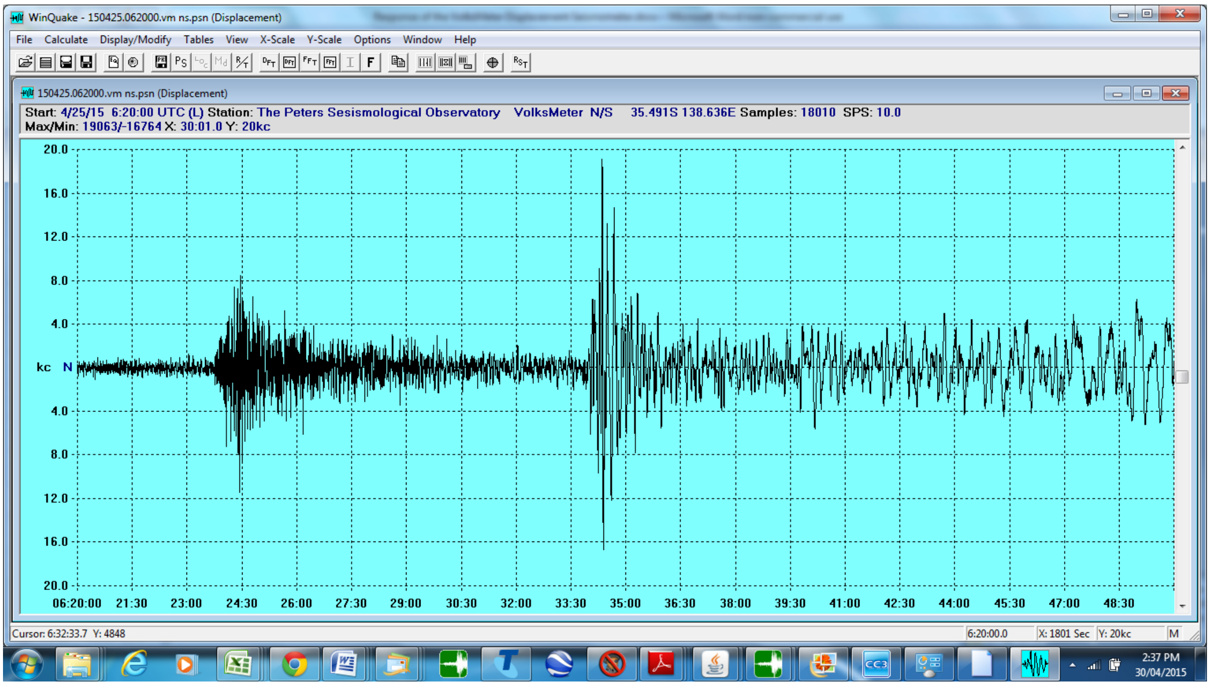
WinQuake - 150425.062000.vm ew.psn (Displacement)

150425.062000.vm ew.psn (Displacement)

Start: 4/25/15 6:20:00 UTC (L) Station: The Peters Sesimological Observatory VolksMeter E/W 35.491S 138.636E Samples: 18010 SPS: 10.0
Max/Min: 26246/-20233 X: 30:01.0 Y: 27kc

Cursor: 6:33:35.1 Y: 4226 | 6:20:00.0 | X: 1801 Sec | Y: 27kc | M

Fig. 1.9.1. **Displacement.** Hindmarsh Valley (TPSO) VolksMeter E/W. Unfiltered. 30 minute trace commencing 2015-04-25 06:20:00. Ending 06:50:00.



WinQuake - 150425.062000.vm ns.psn (Displacement)

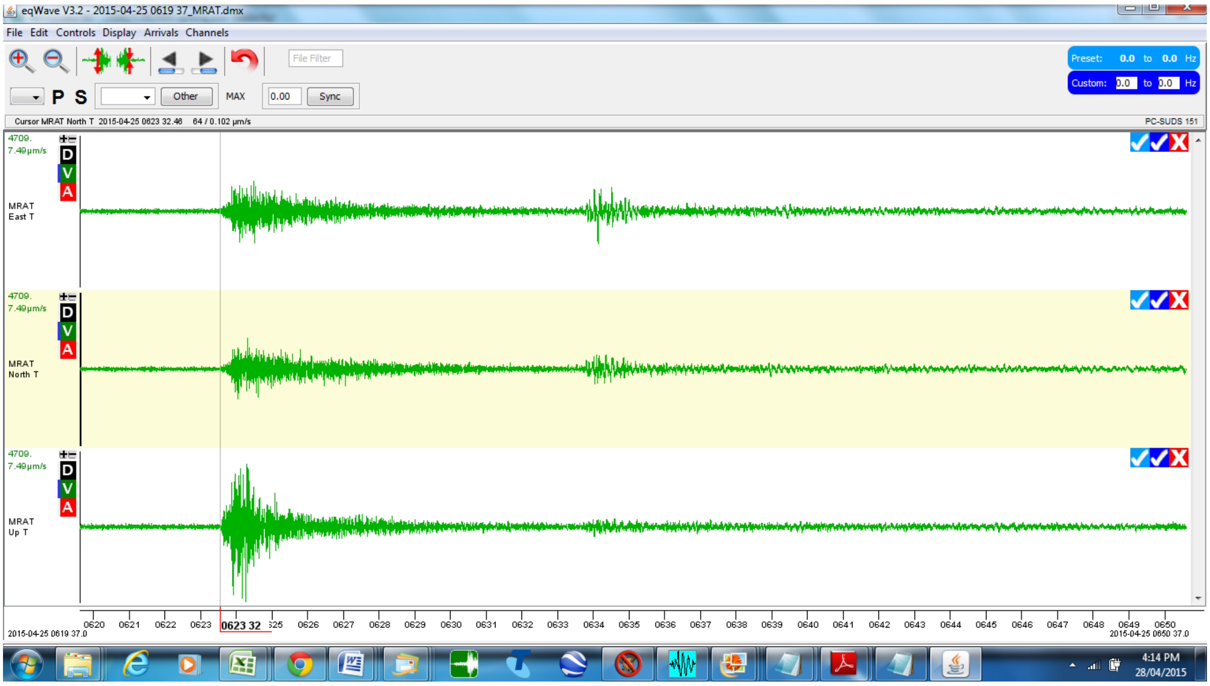
150425.062000.vm ns.psn (Displacement)

Start: 4/25/15 6:20:00 UTC (L) Station: The Peters Sesismological Observatory VolksMeter N/S 35.491S 138.636E Samples: 18010 SPS: 10.0
Max/Min: 19063/-16764 X: 30:01.0 Y: 20kc

Cursor: 6:32:33.7 Y: 4848 | 6:20:00.0 | X: 1801 Sec | Y: 20kc | M

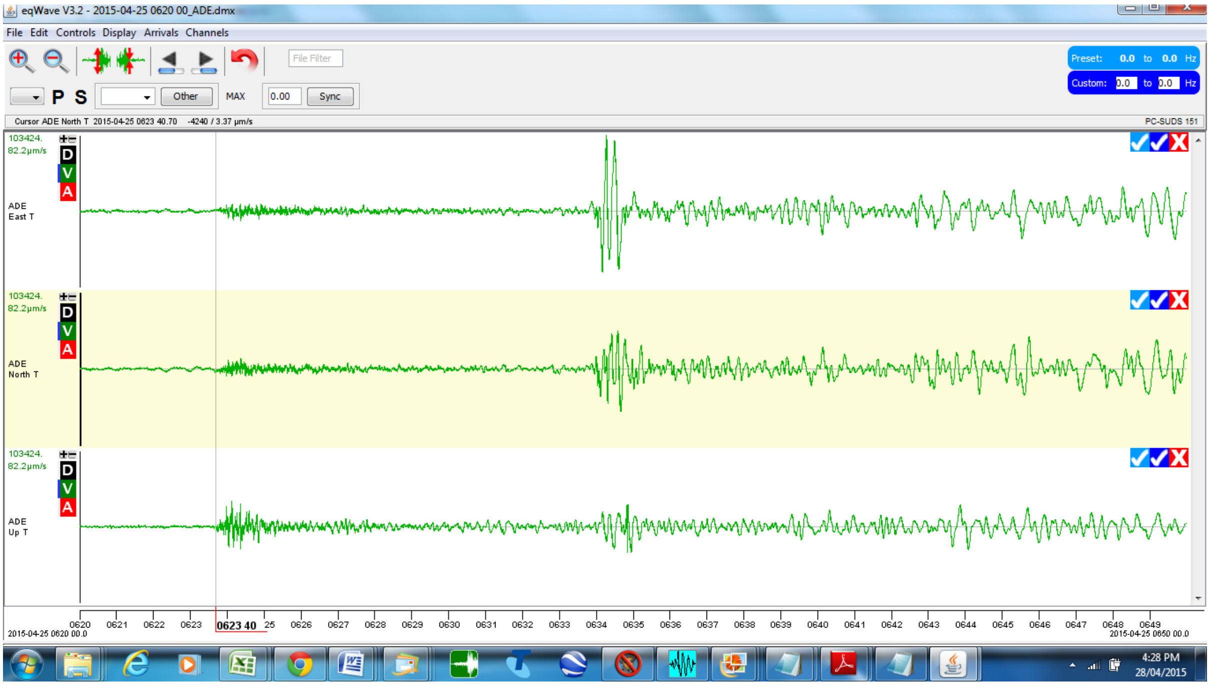
Fig. 1.9.2. **Displacement.** Hindmarsh Valley (TPSO) VolksMeter N/S. Unfiltered. 30 minute trace commencing 2015-04-25 06:20:00. Ending 06:50:00

1.9. Comparison of the responsiveness of the four seismographs to Short Period waves. (Cont.)



Cursor MRAT North T 2015-04-25 0623 32.46 64 / 0.102 µm/s

Fig. 1.9.3. **Velocity.** Mount Rat (MRAT) Guralp 1 second. Unfiltered. 30 minute trace commencing 2015-04-25 06:20:00. Ending 06:50:00. Data provided by Dr. David Love Senior Seismologist Geological Survey Branch PIRSA.



Cursor ADE North T 2015-04-25 0623 40.70 -4240 / 3.37 µm/s

Fig. 1.9.4. **Velocity**. Adelaide (ADE) Guralp 30 second long period. Unfiltered. 30 minute trace commencing 2015-04-25 06:20:00. Ending 06:50:00. Data provided by Dr. David Love Senior Seismologist Geological Survey Branch PIRSA.

1.9. Comparison of the responsiveness of the four seismographs to Short Period waves. (Cont.)

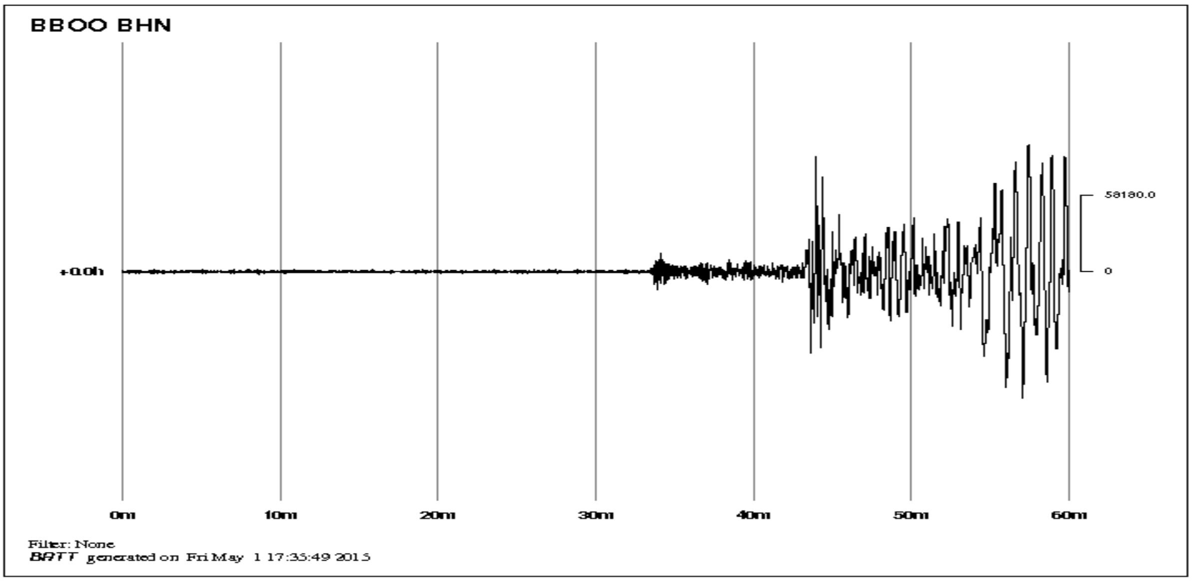


Fig. 1.9.5. **Velocity**. Buckleboo (BBOO) Streckeisen 120 second VBB N/S. Unfiltered. Time commencing 05:50:00. 60 minute long trace. Ending 06:50:00 Chart from GA web site. Note: GA does not provide 30 minute long traces. The END time of the above traces ended at 06:50:00 Note: GA format, where time "0m" means commencing time, here being 05:50:00.

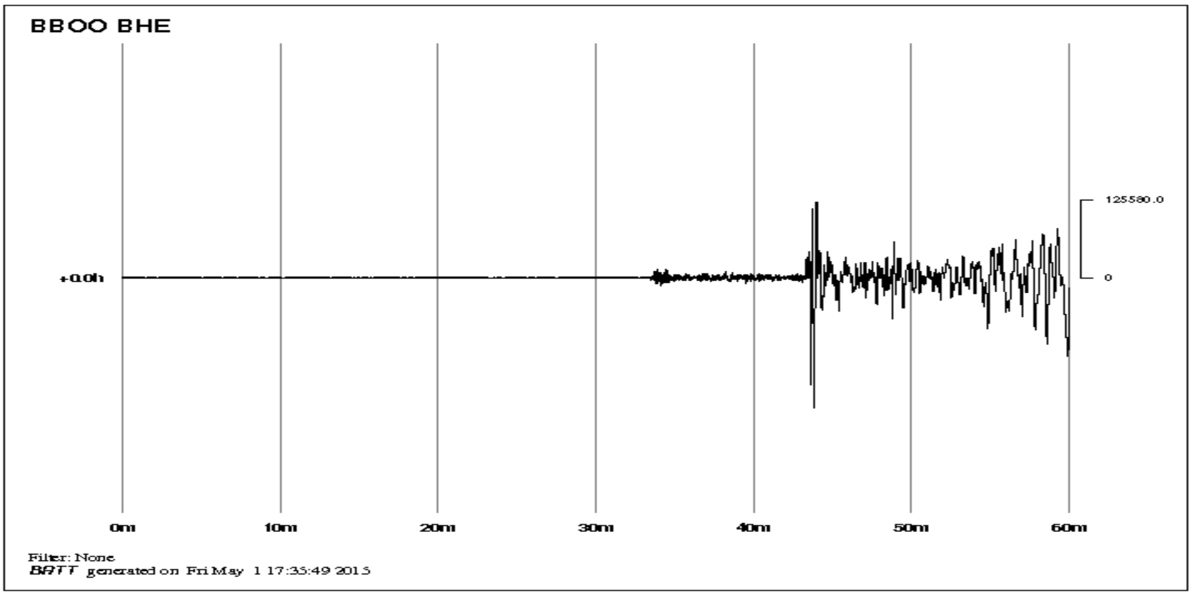


Fig. 1.9.6. **Velocity**. Buckleboo (BBOO) Streckeisen 120 second VBB E/W. Unfiltered. Time commencing 05:50:00. 60 minute long trace. Ending 06:50:00 Chart from GA web site.

1.9. Comparison of the responsiveness of the four seismographs to Short Period waves. (Cont).

1.9.1. Response of horizontals to “P” waves.

As can be readily seen, the response of the horizontal VolksMeter **Displacement** instrument to the arrival of the “P” wave as can be seen in Fig. 1.9.1 and in Fig. 1.9.2,

a) Certainly matches or exceeds the response of the horizontals of the Guralp 1 Second short period **Velocity** instrument as shown in Fig. 1.9.3,

b) Obviously surpasses the response of the horizontals of the Guralp 30 second long period **Velocity** instrument as shown in Fig 1.9.4, and

c) Closely resembles the response of the horizontals of the Streckeisen 120 second VBB **Velocity** instrument as shown in Fig. 1.9.5 and in Fig. 1.9.6.

1.9.2. Response of horizontals to “S” waves.

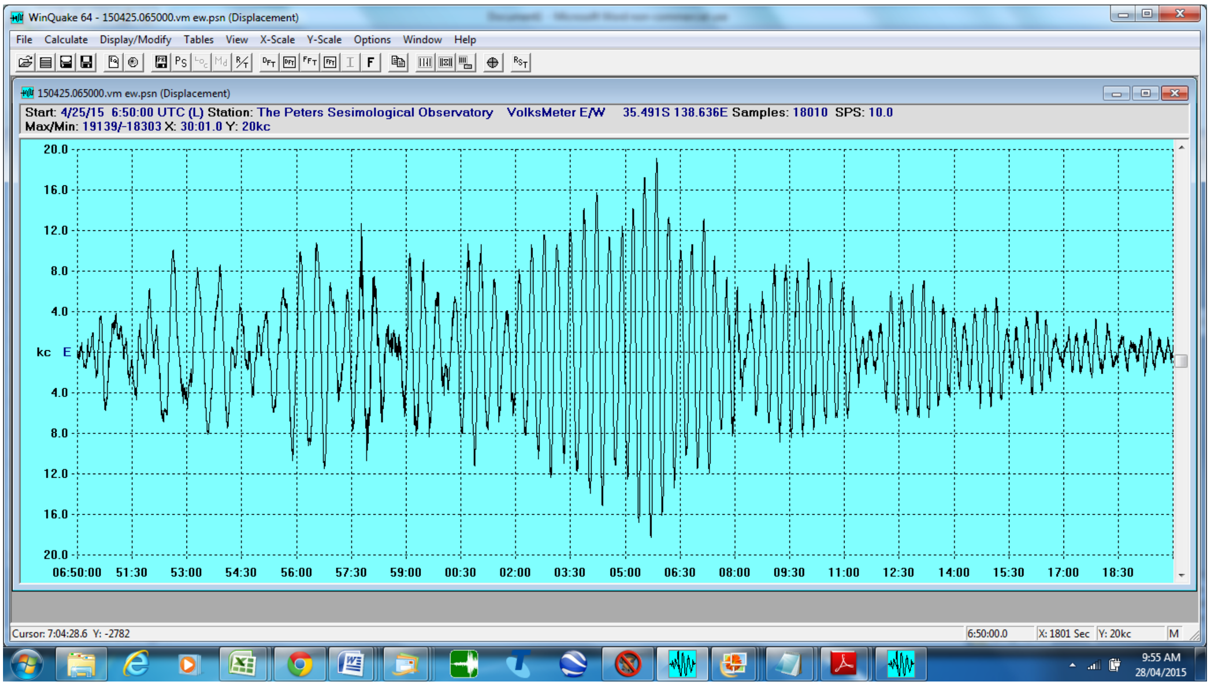
As can be readily seen, the response of the horizontal VolksMeter **Displacement** instrument to the arrival of the “S” wave as can be seen in Fig. 1.9.1 and in Fig. 1.9.2,

a) Greatly exceeds the response of the horizontals of the Guralp 1 Second short period **Velocity** instrument as shown in Fig. 1.9.3,

b) Is at least equal if not better than the response of the horizontals of the Guralp 30 second long period **Velocity** instrument as shown in Fig. 1.9.4, and

c) Closely matches the response of the horizontals of the Streckeisen 120 second VBB **Velocity** instrument as shown in Fig. 1.9.5 and in Fig. 1.9.6.

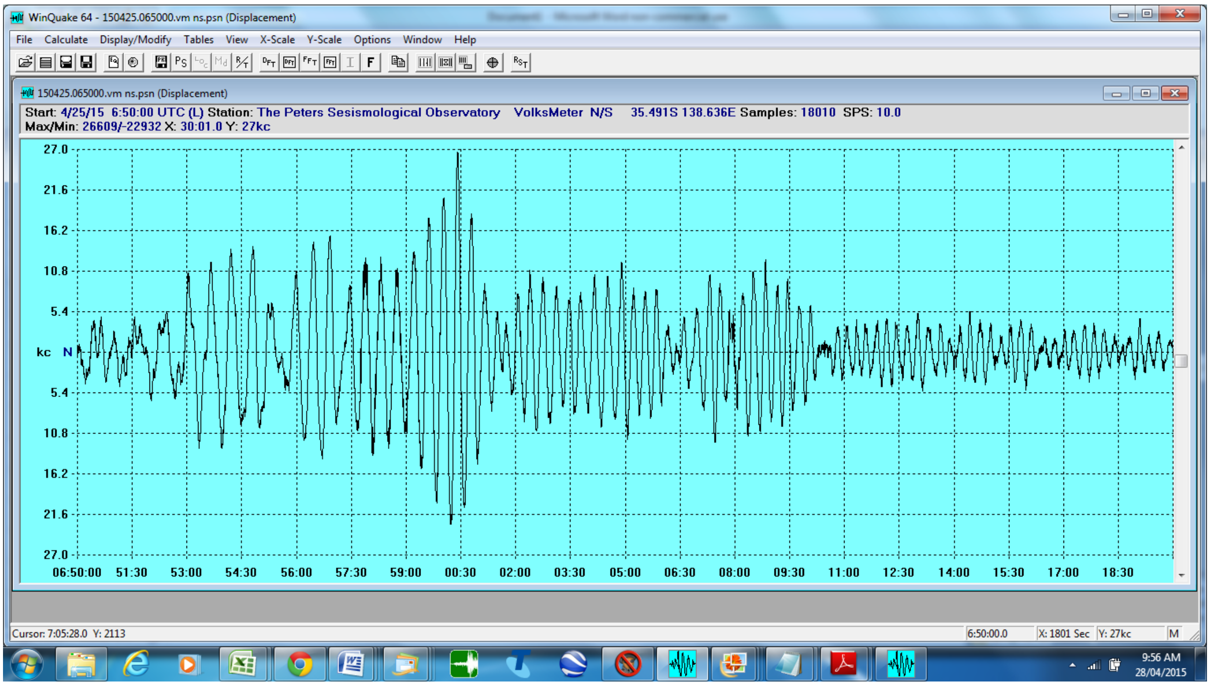
1.10. Comparison of the responsiveness of the four seismographs to Long Period Rayleigh waves.



Start: 4/25/15 6:50:00 UTC (L) Station: The Peters Sesimological Observatory VolksMeter E/W 35.491S 138.636E Samples: 18010 SPS: 10.0
Max/Min: 19139/-18303 X: 30:01.0 Y: 20kc

Cursor: 7:04:28.6 Y: -2782 6:50:00.0 X: 1801 Sec Y: 20kc M

Fig. 1.10.1. **Displacement.** Hindmarsh Valley (TPSO) VolksMeter E/W. Non filtered 30 minute trace. Commencing at 2015-04-25 06:50:00.



Start: 4/25/15 6:50:00 UTC (L) Station: The Peters Sesismological Observatory VolksMeter N/S 35.491S 138.636E Samples: 18010 SPS: 10.0
Max/Min: 26609/-22932 X: 30:01.0 Y: 27kc

Cursor: 7:05:28.0 Y: 2113 6:50:00.0 X: 1801 Sec Y: 27kc M

Fig. 1.10.2. **Displacement**. Hindmarsh Valley (TPSO) VolksMeter N/S. Non filtered. 30 minute trace. Commencing at 2015-04-25 06:50:00.

1.10. Comparison of the responsiveness of the four seismographs to Long Period Rayleigh waves (Cont).

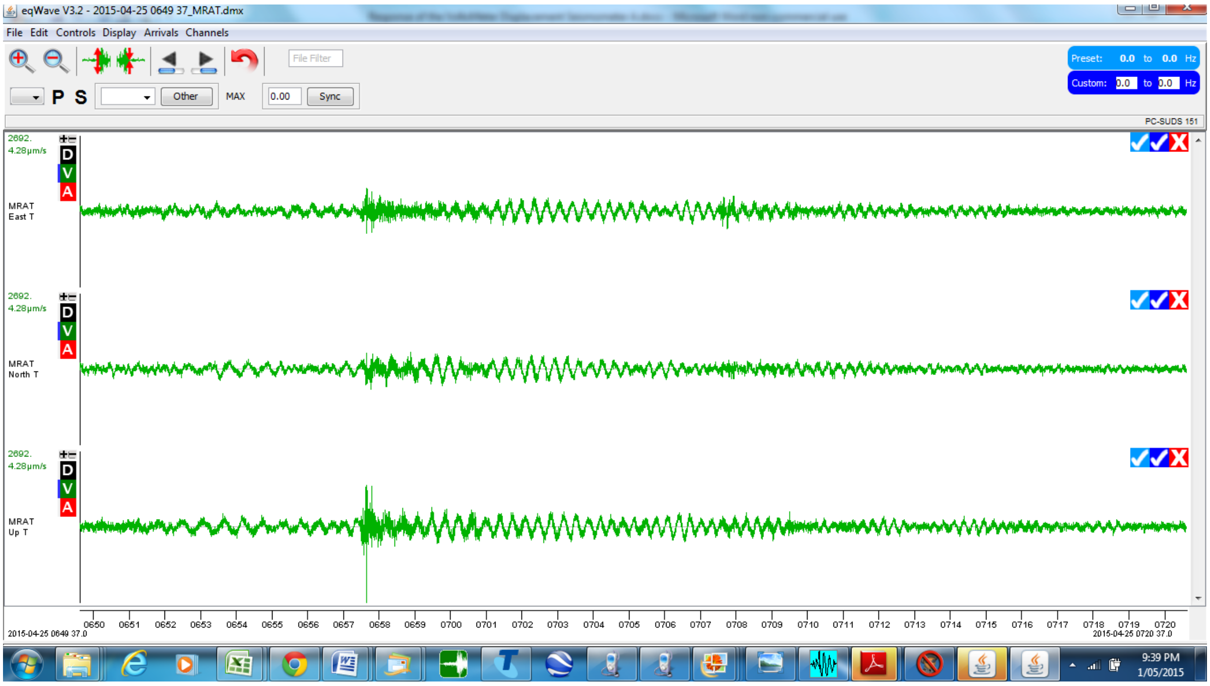


Fig. 1.10.3. **Velocity.** Mount Rat (MRAT) Guralp 1 second. Non-filtered. 30 minute trace. Commencing at 2015-04-25 06:50:00 Note: Nepal 2015-04-25 06:45:21 M6.6 aftershock “P” wave arriving at time 06:57:32. Data provided by Dr. David Love Senior Seismologist Geological Survey Branch PIRSA.

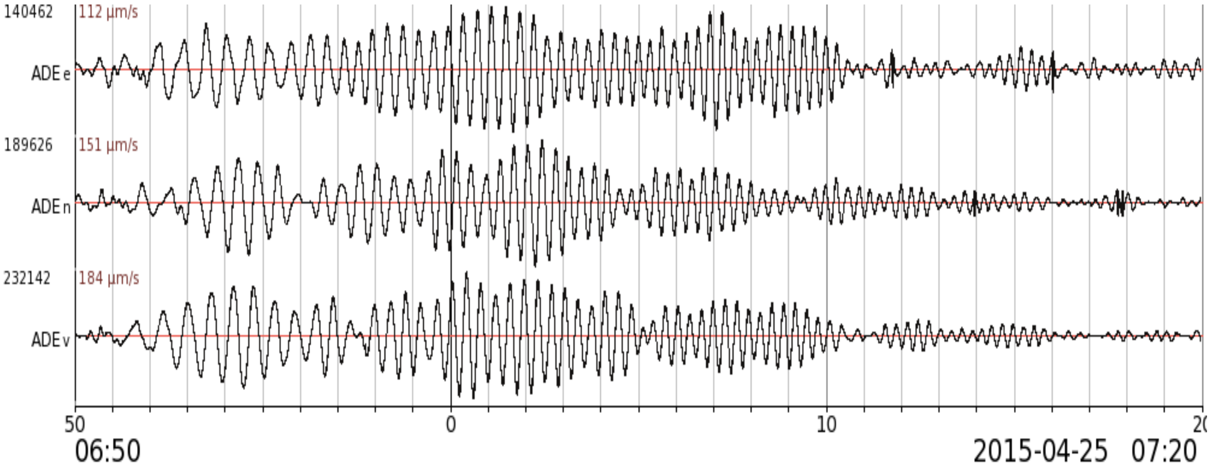


Fig. 1.10.4. **Velocity**. Adelaide (ADE) - 30 Second long period Guralp. - 30 minute trace. Commencing 2015-04-25 06:50:00. Chart from PIRSA web site.

1.10. Comparison of the responsiveness of the four seismographs to Long Period Rayleigh waves (Cont).

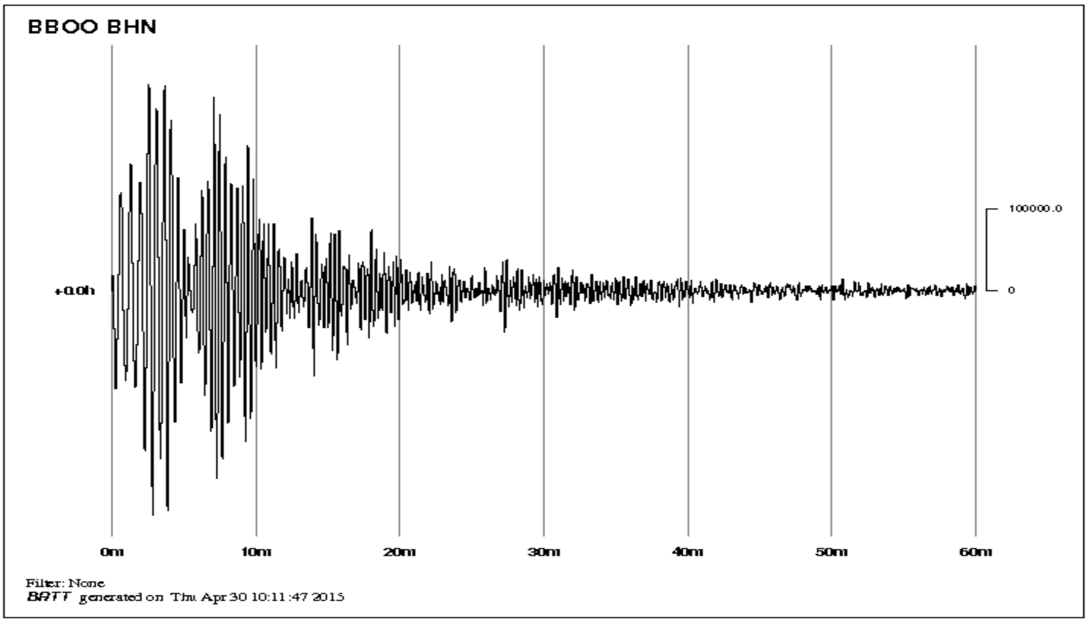


Fig. 1.10.5. **Velocity.** Buckleboo (BBOO) Streckeisen 120 second VBB N/S. Unfiltered. Time commencing 06:50:00 Chart from GA web site. 60 minute long trace. Please note the GA format, where time “0m” means commencing time, here being 06:50:00. Please note GA only provides on the web 60 minute or longer traces.

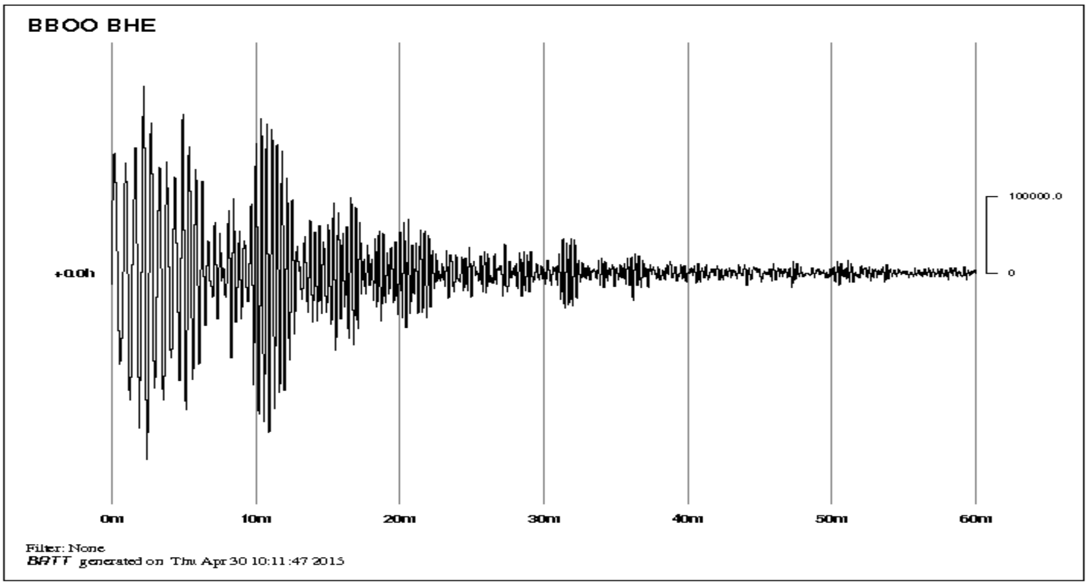


Fig. 1.10.6. **Velocity.** Buckleboo (BBOO) Streckeisen 120 second VBB E/W. Unfiltered. Time commencing 06:50:00. 60 minute long trace. Chart from GA web site.

1.10. Comparison of the responsiveness of the four seismographs to Long Period Rayleigh waves (Cont).

1.10.1. Response of horizontals to Rayleigh waves.

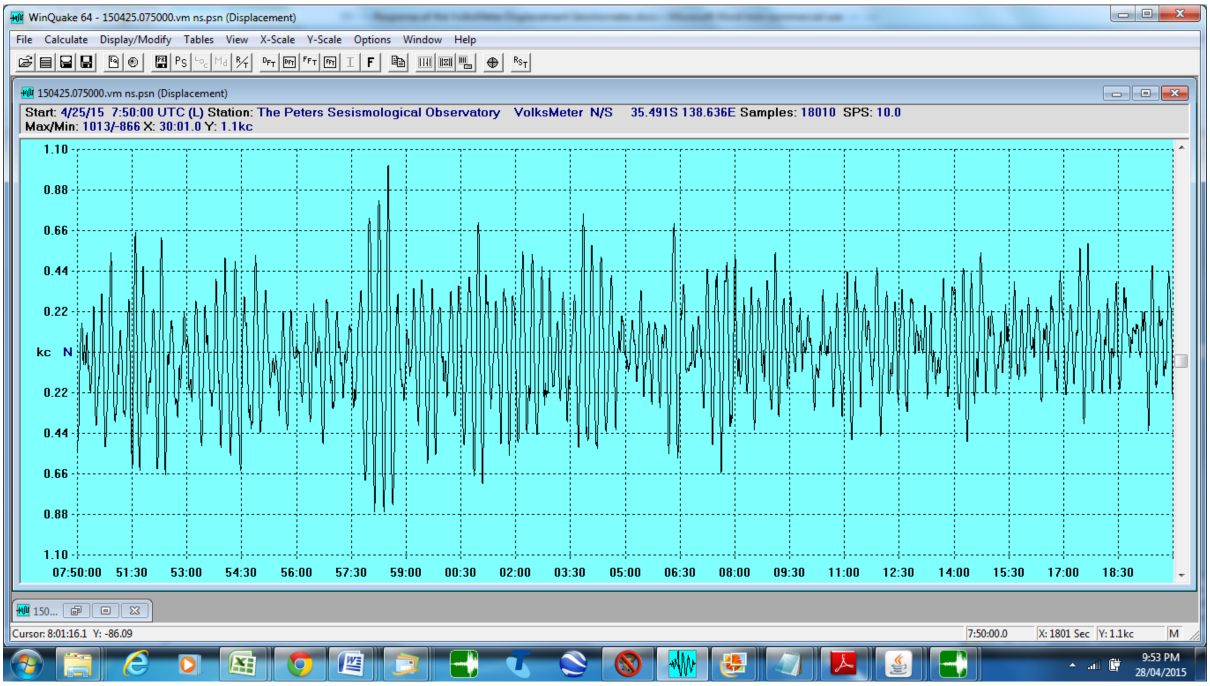
As can be readily seen, the response of the horizontal VolksMeter **Displacement** instrument to the arrival of the Rayleigh waves as can be seen in Fig. 1.10.1 and in Fig. 1.10.2,

a) Greatly exceeds the response of the horizontals of the Guralp 1 Second short period **Velocity** instrument as seen in Fig. 1.10.3,

b) Equals if not exceeds the response of the horizontals of the Guralp 30 second long period **Velocity** instrument as seen in Fig. 1.10.4, and

c) Certainly is commensurate with the response of the horizontals of the Streckeisen 120 second VBB **Velocity** instrument as seen in Fig. 1.10.5 and in Fig. 1.10.6.

1.11. Comparison of the responsiveness of the four seismographs to wave arrivals an hour and a half after “P” arrival – commencing 07:50:00.

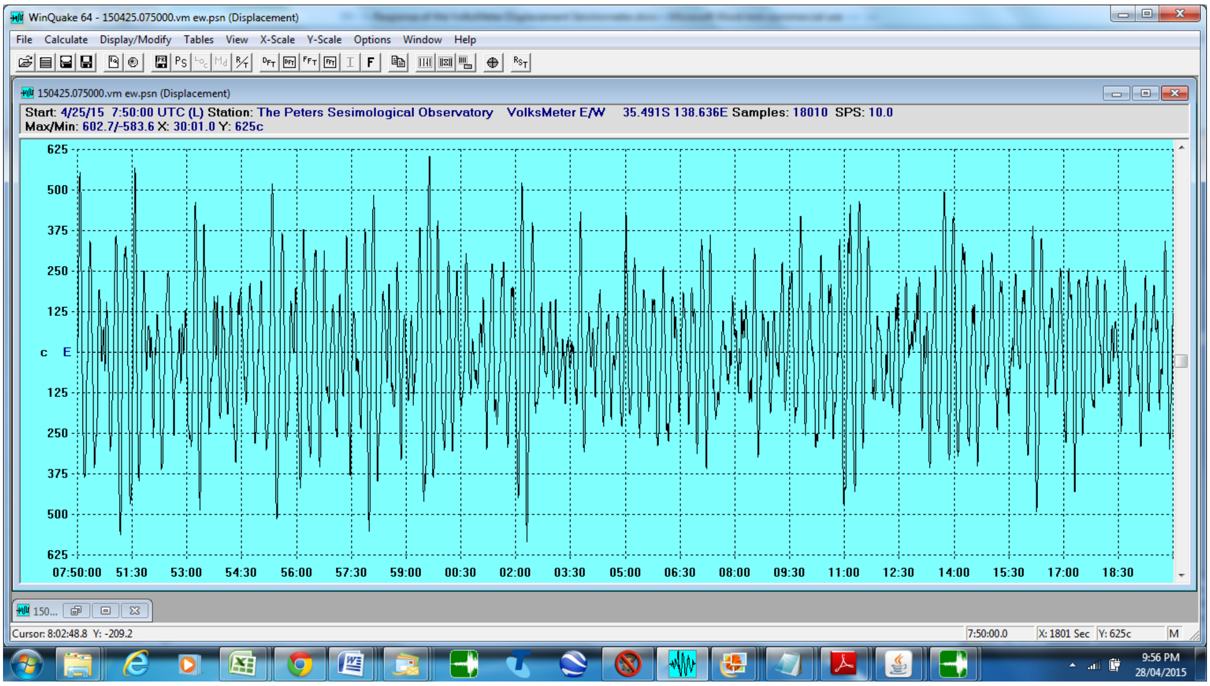

WinQuake 64 - 150425.075000.vm ns.psn (Displacement)

150425.075000.vm ns.psn (Displacement)

Start: 4/25/15 7:50:00 UTC (L) Station: The Peters Sesismological Observatory VolksMeter N/S 35.491S 138.636E Samples: 18010 SPS: 10.0
Max/Min: 1013/-866 X: 30:01.0 Y: 1.1kc

Cursor: 8:01:16.1 Y: -86.09 7:50:00.0 X: 1801 Sec Y: 1.1kc

Fig. 1.11.1. **Displacement.** Hindmarsh Valley (TPSO) VolksMeter N/S. Filtered with 0.1Hz 2 pole filter. Commencing at 2015-04-25 07:50:00. 30 minute long trace.


WinQuake 64 - 150425.075000.vm ew.psn (Displacement)

150425.075000.vm ew.psn (Displacement)

Start: 4/25/15 7:50:00 UTC (L) Station: The Peters Sesimological Observatory VolksMeter E/W 35.491S 138.636E Samples: 18010 SPS: 10.0
Max/Min: 602.7/-583.6 X: 30:01.0 Y: 625c

Cursor: 8:02:48.8 Y: -209.2 7:50:00.0 X: 1801 Sec Y: 625c

Fig. 1.11.2. **Displacement.** Hindmarsh Valley (TPSO) VolksMeter E/W. –Filtered with 0.1Hz 2 pole filter. Commencing at 2015-04-25 07:50:00. 30 minute long trace.

1.11. Comparison of the responsiveness of the four seismographs to wave arrivals an hour and a half after “P” arrival – commencing 07:50:00 (Cont).

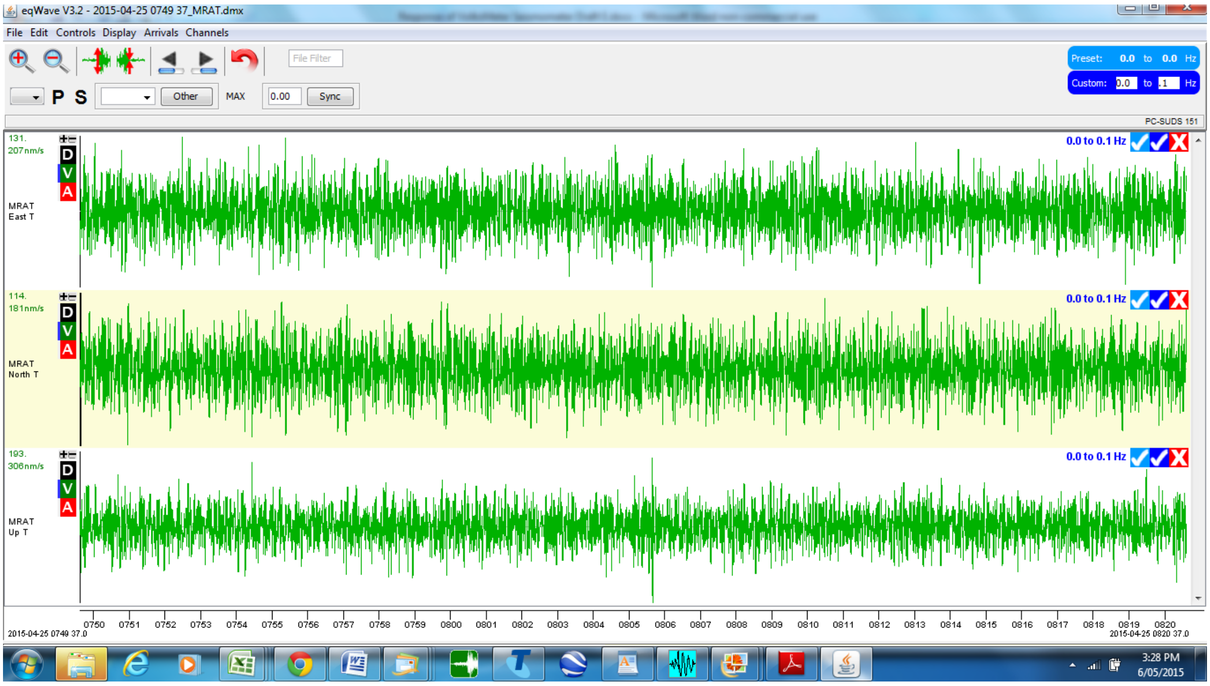


Fig. 1.11.3. **Velocity**. Mount Rat (MRAT) Guralp 1 second. Commencing at 2015-04-25 07:50:00. 30 minute long trace. Filtered 0.1 Hz Data provided by Dr. David Love Senior Seismologist Geological Survey Branch PIRSA.

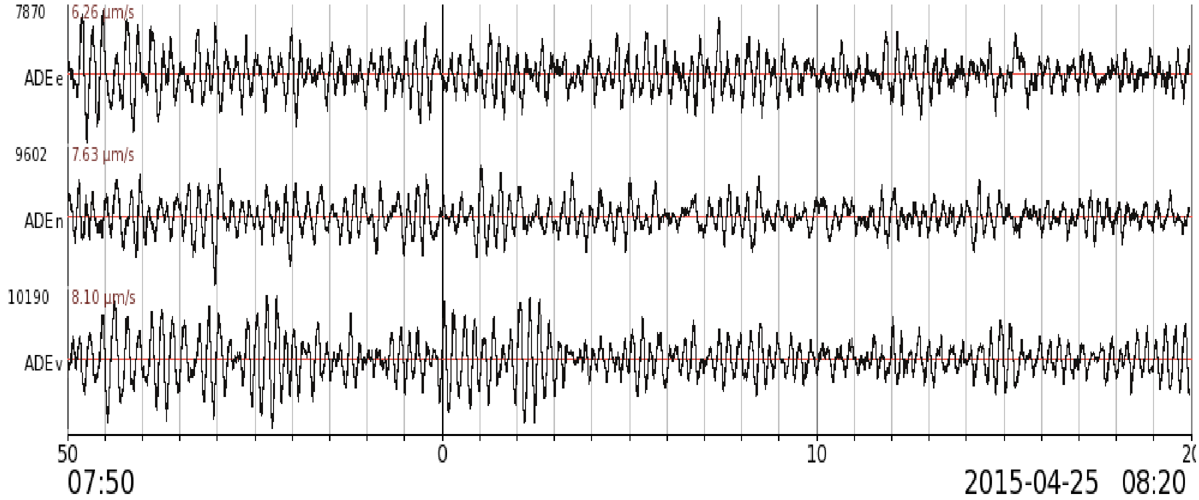


Fig. 1.11.4. **Velocity.** Adelaide (ADE) 3 axis Guralp 30 second long period. Commencing at 2015-04-25 07:50:00. 30 minute long trace. Chart from PIRSA web site.

1.11. Comparison of the responsiveness of the four seismographs to wave arrivals after an hour and a half after “P” arrival – 07:50:00 (Cont).

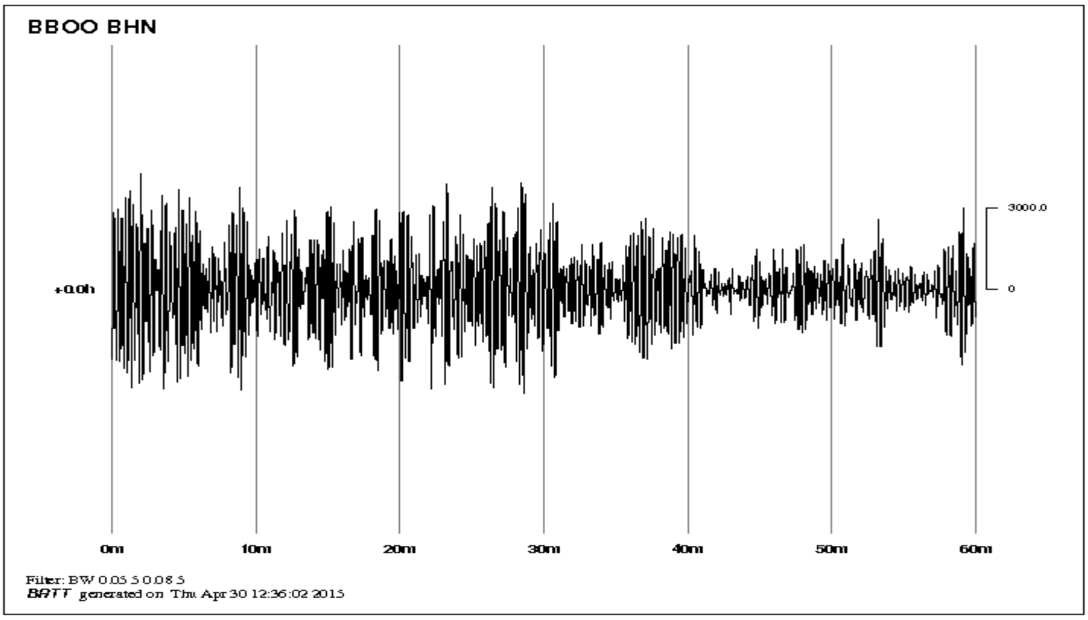


Fig. 1.11.5. **Velocity.** Buckleboo (BBOO) Streckeisen 120 second VBB N/S. Filtered 0.7Hz Butterworth. Time commencing 07:50:00. 60 minute long trace Chart from GA web site. Note: Buckleboo VBB traces are <u>both 60 minutes long</u>. Note: GA format, where time “0m” means commencing time, here being 07:50:00.

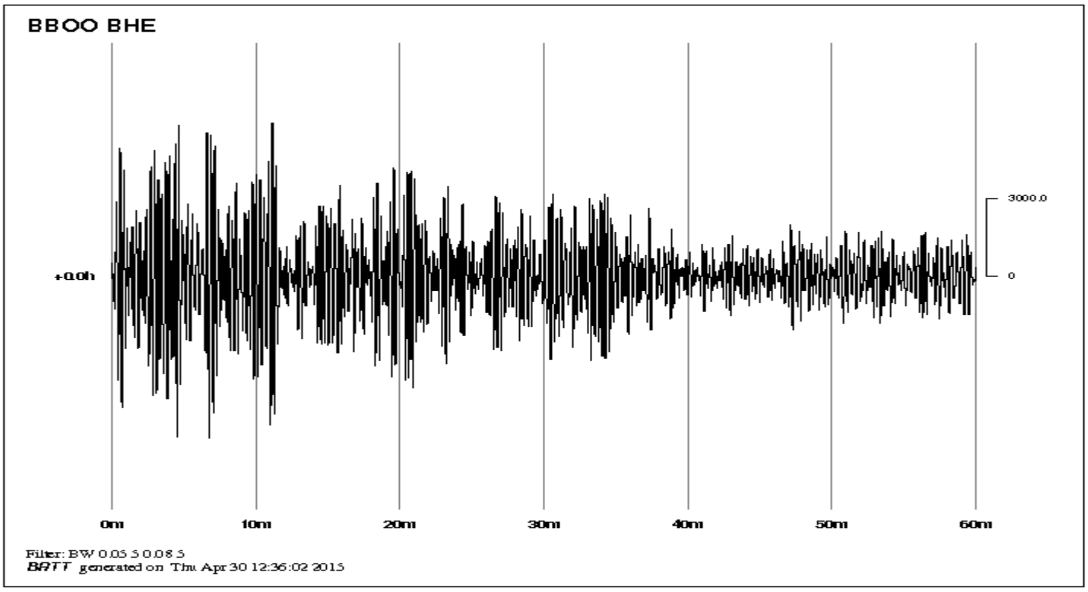


Fig. 1.11.6. **Velocity.** Buckleboo (BBOO) Streckeisen 120 second VBB E/W - Filtered 0.07Hz Butterworth. Time commencing 07:50:00. 60 minute long trace Chart from GA web site.

1.11. Comparison of the responsiveness of the four seismographs to wave arrivals an hour and a half after “P” arrival – commencing 07:50:00 (Cont).

1.11.1 Response of horizontals to waves commencing 07:50:00.

As can be readily seen, the response of the horizontal VolksMeter **Displacement** instrument to the arrival of waves commencing 07:50:00, being an hour and a half after the arrival of the “P” waves, as can be seen in Fig. 1.11.1 and in Fig. 1.11.2,

> a) Has no competition from the horizontals of the Guralp 1 Second short period **Velocity** instrument as this short period velocity instrument shows it is rather insensitive to waves having a period much longer than the natural resonance of the instrument.
>
> b) Has added definition and detail as compared to the response of the horizontals of the Guralp 30 second long period **Velocity** instrument, and
>
> c) Clearly and unambiguously shows the same wave train patterns as seen in the response of the horizontals of the Streckeisen 120 second VBB **Velocity** instrument.

1.12. Summary of Part 1.

By simply comparing the horizontal traces of the four seismographs, then the responsiveness of the horizontal VolksMeter **Displacement** seismograph to the different frequency waves coming from the Nepal M7.8 quake has been shown in each case to be at least equal to the responsiveness of any one of the three horizontal **Velocity** seismographs to these various waves.

This demonstrated broadband response of the horizontal VolksMeter **Displacement** seismometer is noteworthy, especially when one considers the fact that each **Velocity** seismograph is itself tuned to give maximum respond to a specific frequency or a specific range of frequencies.

The horizontal VolksMeter **Displacement** seismometer has indeed shown the benefit of its intrinsic design feature; i.e., for earth motions having periods longer than its 1.09 second corner period, its response is **directly proportional** to these long period earth motions.

Part 2. Earth Tides.

The VolksMeter being a **Displacement** instrument, can in theory, measure periods ranging from fractions of a second to months. This is an astounding range, covering 9 orders of magnitude!

2.1 Earth tides of approximately 12½ hours.

What is the ability of the VolksMeter **Displacement** seismograph to measure the twice daily Earth tide of some 0.000023 Hz being approximately 43,000 seconds duration. That is, the semidiurnal Earth tide of approximately 12½ hours.

Erhard Wielandt has said of Earth tides,

> *"For broadband seismographs at quiet sites … whilst normally invisible in the raw data, they* [Earth tides] *may be extracted by low-pass filtration with a corner frequency of about 1mHz …with a sampling rate of 1 per second or less*.
>
> *A seismic broadband station that records Earth's tides is likely to be up to international standards."* IASPEI Chapter 5.6.2.

So just how extremely quiet must a seismic vault be, to be "*up to international standards*", in order for an extremely expensive and an extremely sensitive broadband seismograph to have any chance at all of recording Earth tides. And even then the Earth tides are usually only visible after filtering the data.

Or turning this around.

Can a horizontal VolksMeter **Displacement** seismometer operate in a temperature stable but extremely noisy seismic vault, and still record Earth tides.

The Peters Seismological Observatory (TPSO) located just 6 kms away from the Great Southern Ocean where microseism background noise is always significant, and severe whenever a storm system approaches, falls far short indeed, far far short, with respect to the international standards that are required by the New Low Noise Model (NLNM) for seismic stations.

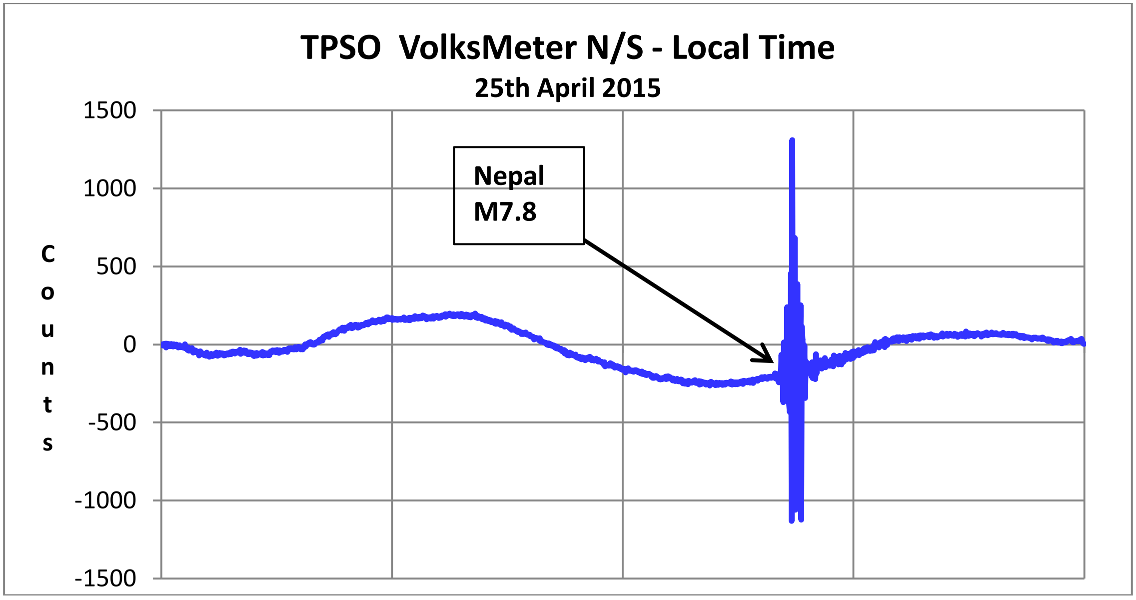


Fig. 2.1(a). Semidiurnal 12½ hour Earth tide shown over a 24 hour period as recorded by the pendulous horizontal VolksMeter **Displacement** seismometer at TPSO - 25th April 2015, [Adelaide Local Time]. One minute average counts. Unfiltered.

2.1 Earth tides of approximately 12½ hours (Cont).

Fig. 2.1(a). above clearly showing the horizontal VolksMeter **Displacement** seismometer competently recording Earth tides of some 12½ hours when housed in a temperature stable seismic vault, even in the presence of severe microseism background noise.

The data for Fig. 2.1(a). has been taken directly from the horizontal VolksMeter **Displacement** seismometer's one minute average count "Data Average.log" file.

The "Data Average .log" file, is a file automatically generated by the WinSDR software running the horizontal VolksMeter **Displacement** seismometer, with WinSDR software developed by Larry Cochrane and supplied with the horizontal VolksMeter **Displacement** seismometer.

With Larry Cochrane's WinSDR software and WinQuake software being used to producing the 24 hour long N/S and the E/W horizontal VolksMeter **Displacement** seismographs as shown in Part 1.

2.2. Comparison of the 12½ hour Earth tide on the 25th April 2015.

Comparison of the 12½ hour Earth tide as recorded by the N/S pendulous horizontal VolksMeter **Displacement** seismometer located at TPSO, South Australia, with the 12½ hour Earth tide as recorded for the same day [local time] by the N/S horizontal pendulous Grotta Gigante **Displacement** seismometer at Trieste, Italy.

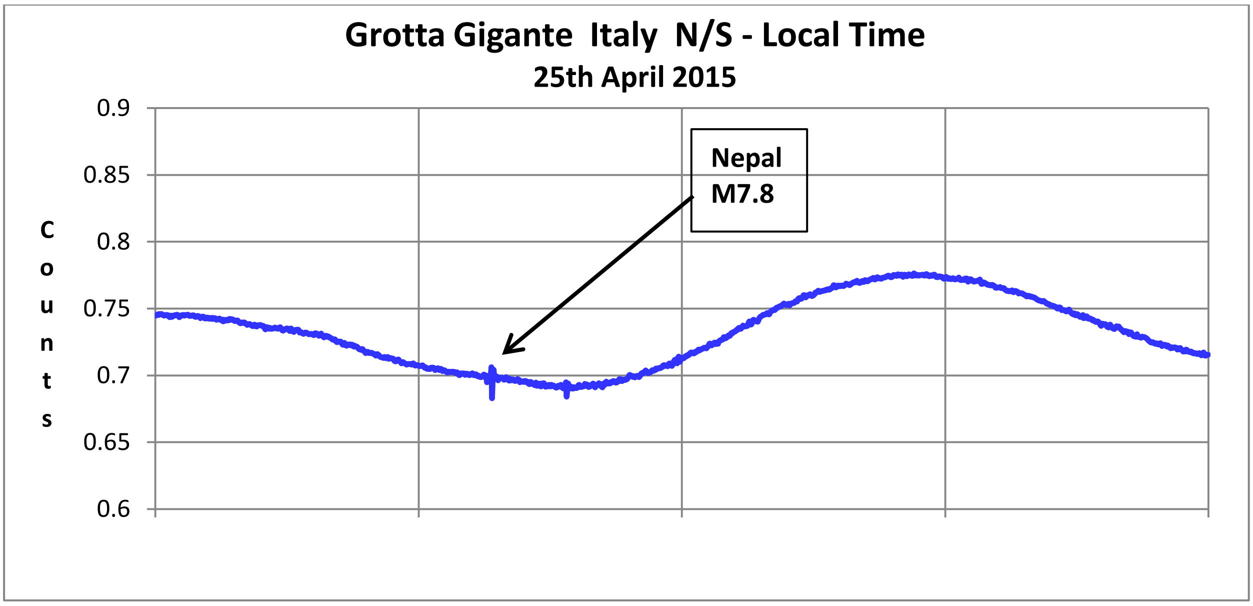


Fig. 2.1(b). Semidiurnal 12½ hour N/S Earth tide shown over 24 hour period as recorded by the pendulous horizontal **Displacement** seismometer located at Grotta Gigante, Trieste, Italy. - 25th April 2015, [Italian Local Time]. One sample taken per minute. <u>Unfiltered.</u>

For the 24 hours of the 25th April 2015 the N/S Earth tide as recorded in Fig. 2.1(a). [Local time] at TPSO, South Australia, and the N/S Earth tide as recorded in Fig. 2.1(b). [Local time] at Grotta Gigante, Trieste, Italy, are as expected, remarkably similar.

Both being horizontal pendulous **Displacement** instruments.

With TPSO data being one minute average counts and the Grotta Gigante data being one sample taken every minute.

2.3. Why Nepal M7.8 earthquake hardly registered on Grotta Gigante.

The question must now be asked.

Why is the 24 hour long recording showing the N/S Earth tide for that particular day [local time] so remarkably similar for both instruments in different hemispheres and separated by some 124 Degrees Longitude, yet the impact of the M7.8 Nepal earthquake on TPSO is impressive yet barely makes it onto the Grotta Gigante trace.

Why is this so, particularly when Grotta Gigante is located much closer to the M7.8 Nepal epicentre, being some 6,500 Kms and TPSO is located further away being some 9,000 km from the epicentre.

2.3.1. Method of recording data.

2.3.1.1. VolksMeter Displacement Seismometer.

Regarding the one minute average count for the VolksMeter **Displacement** Seismometer .

Why should there be any earthquake at all, showing on a trace that shows the average count for each minute. Surely the 24 hour long trace of “one minute average counts”, surely the one minute averaging of data removes any transients including transients from any earthquake.

The answer is that as the period of the seismic waves passing thru the station increases then symmetry within the 60 second long recording period decreases. Longer period waves like Rayleigh Waves have for example a frequency of perhaps 0.043 Hz [23 seconds] hence having 2.6 cycles during the particular 60 second averaging period, with the half cycle of the Rayleigh Wave biasing that particular 60 second average count either up or down. Resulting in significant fluctuations in the one minute averages during the time these longer period waves like Rayleigh Waves pass thru.

2.3.1.2. Grotta Gigante Displacement Seismometer.

Regarding the one sample taken each minute for the Grotta Gigante **Displacement** trace.

Again, the same applies, any one sample taken each minute, will result in significant fluctuations in the one minute samples taken, during the time these longer period waves like Rayleigh Waves pass thru.

Therefore we should see approximately the same displacements on both the horizontal pendulous Grotta Gigante **Displacement** seismometer trace taking one sample every minute as long period waves pass thru, as on the horizontal pendulous VolksMeter **Displacement** seismometer trace taking the one minute average count of the data as long period waves pass thru.

2.3.2. Design of instruments - 1 second and 360 second periods.

But we barely see any record of the M7.8 earthquake on the Grotta Gigante trace, why?

The answer lies in the intrinsic design of each horizontal pendulous **Displacement** instrument.

The pendulous horizontal VolksMeter Displacement instrument has a 1.09 second natural period, and the pendulous horizontal Grotta Gigante Displacement instrument has a 360 second natural period.

2.3.2.1 VolksMeter 1.09 second natural period.

The horizontal pendulous VolksMeter **Displacement** seismograph has a natural period of 1.09 Seconds.

Therefore the output will be directly proportional to any and to all accelerations/displacements/tilt from any seismic waves or earth motion that have a period longer than 1.09 Seconds. Including an output directly proportional to any “P” and “S” waves longer than about 1 second period, an output directly proportional to “Rayleigh Waves” of some 20 seconds period, emanating from the M7.8 Nepal earthquake, and including an output directly proportional to any eigenmodes of some 1,000 seconds period or greater and an output directly proportional to any Earth tides of 12½ hours or longer.

All these will be recorded on the horizontal VolksMeter **Displacement** seismometer’s trace being directly proportional to actual ground **acceleration/tilt.**

2.3.2.2 Grotta Gigante 360 second natural period.

The horizontal pendulous Grotta Gigante **Displacement** seismometer has Zöllner pendulums 95 metres long and has a natural period set at 360 Seconds.

Therefore the horizontal Grotta Gigante **Displacement** seismometer’s output will be directly proportional to any and to all accelerations/displacements/tilt from any seismic waves or earth motion that have a period longer than 360 Seconds. Including an output directly proportional to any eigenmodes of some 1,000 seconds or greater and an output directly proportional to any Earth tides of 12½ hours or longer.

These eigenmodes and Earth tides will all be recorded on the horizontal Grotta Gigante **Displacement** seismometer’s trace being directly proportional to actual ground **acceleration/tilt.**

However.

Any seismic waves passing thru having periods shorter than 360 seconds will be subjected to attenuation.

Because of the 20 dB per decade decrease in response at periods shorter that 360 seconds, then the twenty second long “Rayleigh Waves” from the M7.8 Nepal earthquake will be greatly attenuated and the one second long “P” waves and “S” waves from the M7.8 Nepal earthquake will be severely attenuated.

Hence we can now see why there is nothing of the M7.8 Nepal earthquake’s “P” and “S” waves showing on the Grotta Gigante trace, and why there is but just a hint of the M7.8 Nepal earthquake’s Rayleigh Waves upon the Grotta Gigante trace, and yet why the 45,000 second 12½ hour Earth tide on the Grotta Gigante trace is so very clearly presented.

Showing why the Grotta Gigante Displacement seismograph is ideally suited to recording eigenmodes and Earth tides of days, months years and decades.

2.4. Amplitude (nrad) of Earth tides.

"Depending on the location and direction of measurement, they [Earth tides] *cause tilting of the Earth´s crust in the 70 nrad amplitude range with a semidiurnal period (~12.5 h)"* Michael Rivero.

http://www.researchgate.net/profile/Michel_Rivero/publication/270217245_Precise_tiltmeter_and_inclinometer_based_on_commercial_force_compensation_cells/links/54a313d10cf267bdb9042ea8.pdf

Fig2.1(a). above, shows the 12½ hour Earth tide recorded by the N/S horizontal VolksMeter **Displacement** seismometer at TPSO, as having amplitude of approximately some 200 Counts.

The calibration of the horizontal pendulous VolksMeter **Displacement** seismometer located at TPSO being 3.06 Counts/nanoradian meaning 200 Counts equates to some 65 nanoradians.

With Michael Rivero confirming above, that 70 nanoradians is the typical range of Earth tide amplitude.

(Although of course Earth tides vary in amplitude according to the latitude of the location, and Earth tide amplitude varies twice over the monthly lunar cycle, and varies over the year.)

70 nanoradians being the angle the thickness of a human hair [1/10th mm] subtends at a distance of about 1.4 kms.

2.5. Earth tide variation with a period of 2 x 7.38 days.

The 7.38 day lunar quadrature cycle of Earth tide is a result of the 29.53 days that it takes for the moon to orbit the earth.

When the three bodies, earth/moon/sun lie in a straight line then this is called a syzygy. This occurs twice a lunar month, and twice a lunar month seen from earth, the moon is 90 degrees from the sun, called a Quarter moon

Over the lunar month quadrature causes modulation of the Earth tide, wherein the semidiurnal 12½ hour Earth tides and the 24 hour diurnal Earth tides rise and fall. It is analogous to the variation in ocean tide magnitude between the so-called spring tide and neap tide.

The detection of amplitude changes of the daily Earth tides requires considerable analytical effort to extract the variation from noise, such as the disturbances associated with the diurnal thermal signature.

Here we use autocorrelation, an extremely powerful analytical tool to show periodicities.

The following set of charts show for both the N/S and the E/W channels of the horizontal VolksMeter **Displacement** seismometer, from the 17th April 2015 to the 4th June 2015, the

- Raw data records,
- Raw data records, band-pass filtered two pole, 2 cycles a day, and
- Autocorrelations of the band-pass filtered records.

2.5.1. VolksMeter N/S response to Earth tide quadrature cycle of 7.3 days.

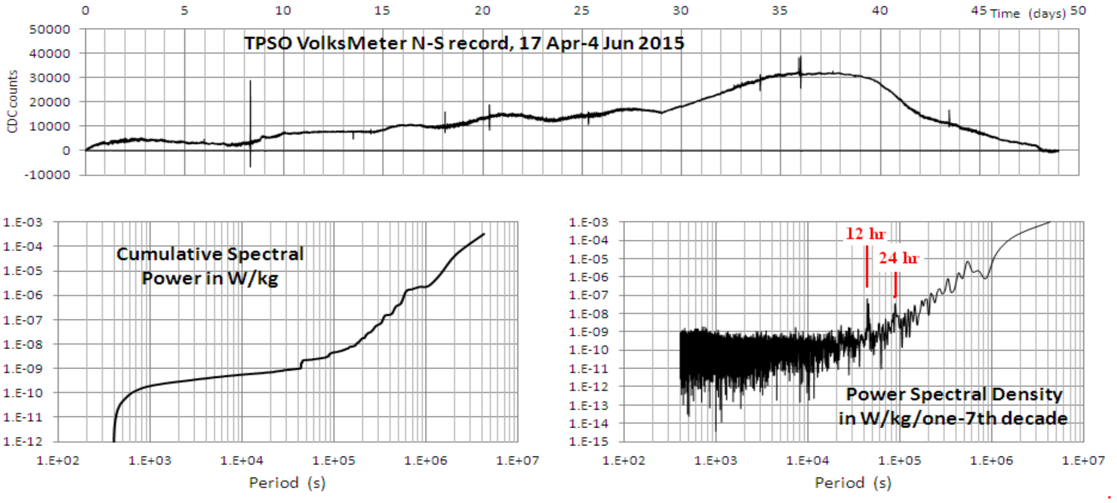


Fig. 2.5.1(a). Raw data. N/S record of VolksMeter **Displacement** seismometer for 17th April to 4th June 2015 showing a direct correlation of TILT with area barometric pressure gradient. (It is to be noted that pendulums are rather immune to buoyancy effects from changing barometric pressure).

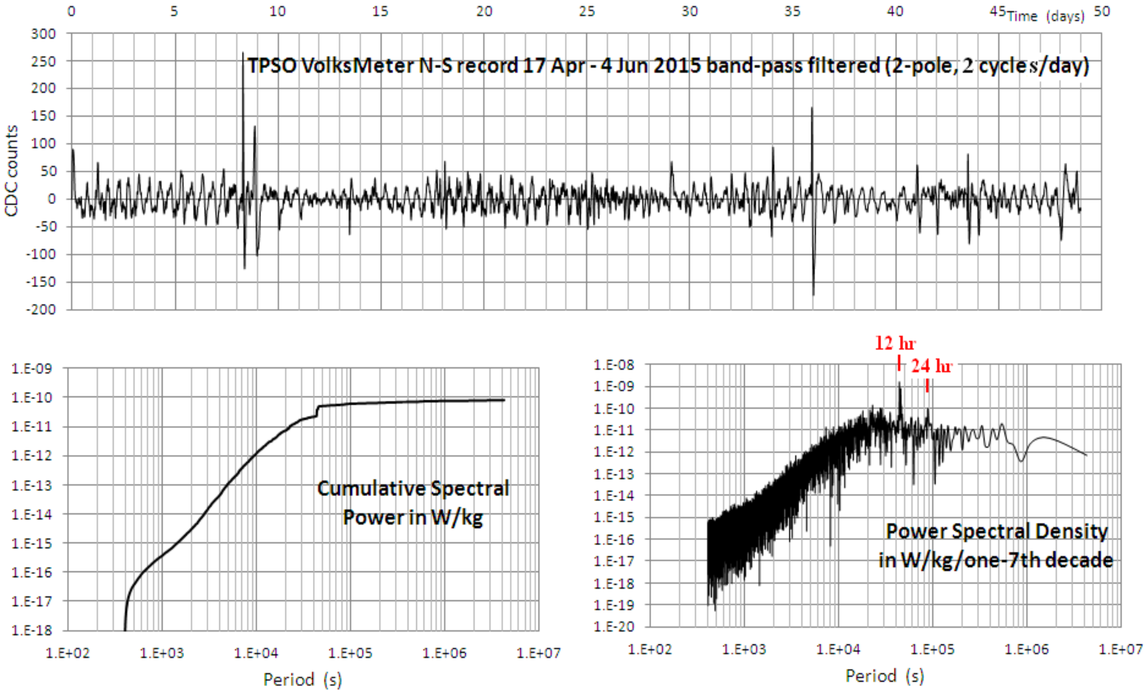


Fig. 2.5.1(b). Band-pass filtered (2-pole, 2 cycles a day). N/S record of horizontal VolksMeter **Displacement** seismometer from 17th April 2015 to 4th June 2015 .

2.5.1. VolksMeter N/S response to Earth tide quadrature cycle of 7.3 days (Cont).

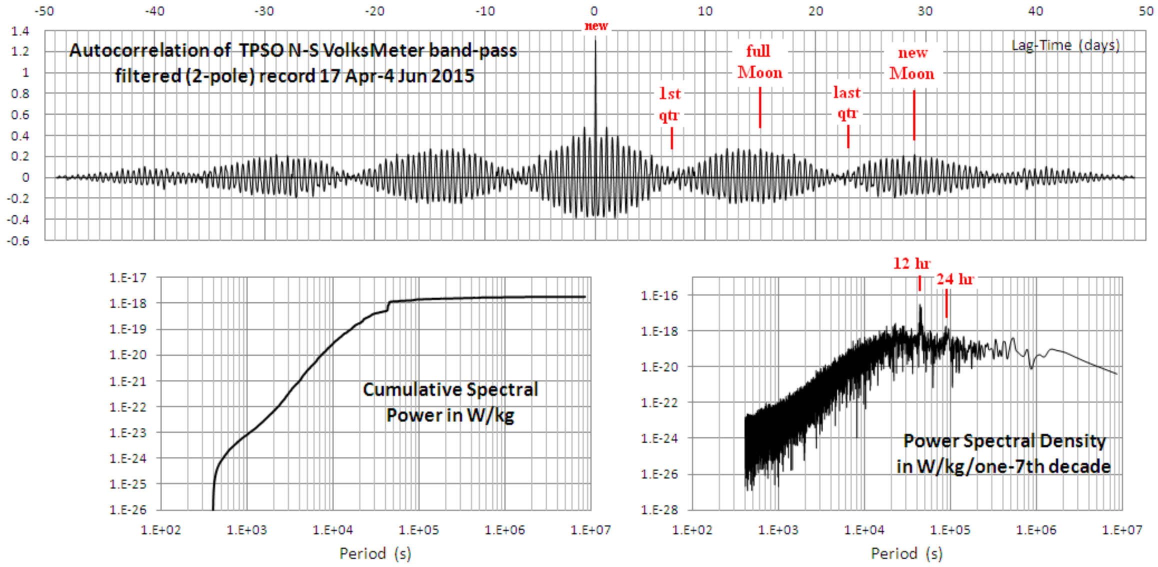


Fig. 2.5.1(c). Autocorrelation of band-pass filtered 2 pole. N/S record of horizontal VolksMeter **Displacement** seismometer from 17th April 2015 to 4th June 2015 .

Indicated upon the autocorrelation chart as zero time, is the time of the New Moon, the time of the 1st Quarter moon, the time of the Full Moon, time of the Last Quarter Moon, and the time again, of the New Moon.

As can be seen from this N/S case, for the recording period from the 17th April 2015 to the 4th June 2015, there are significant variations in amplitude of the Earth tides. The autocorrelation of the bandpassed record shows the influence of quadrature that happens every 7.3 days after a full Moon or a new Moon—by the minima at ± 7 days and ± 22 days.

In addition, in the Power Spectral Density Chart of Fig. 2.5.1(c). being Watts/kg/one-7th decade, the 12½ hour Earth tide and the 24 hour Earth tide is clearly in evidence.

2.5.2. VolksMeter E/W response to Earth tide quadrature cycle of 7.3 days.

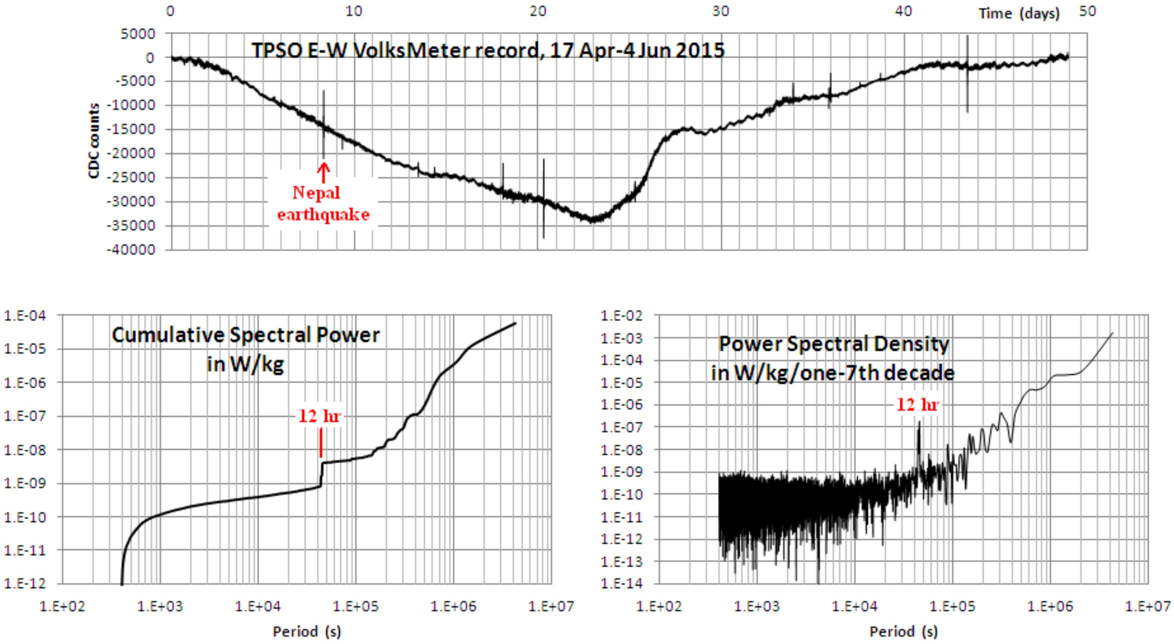
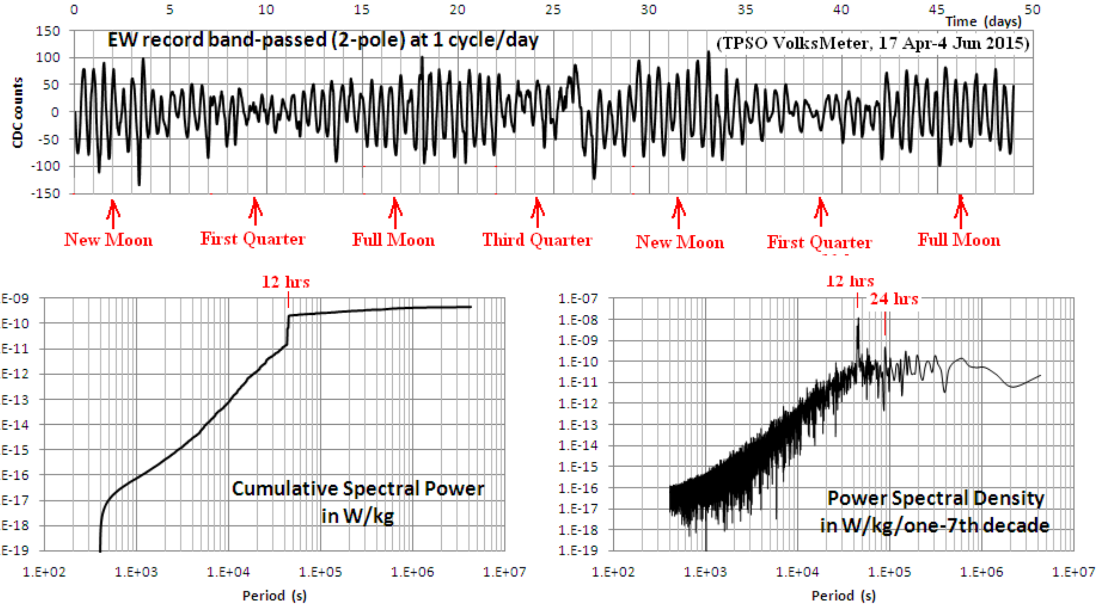


Fig. 2.5.2(a). Raw data. E/W record of VolksMeter **Displacement** seismometer for 17th April to 4th June 2015. Showing Nepal M7.8 earthquake, and other smaller but nearer quakes.



2.5.2(b). Band-pass filtered (2-pole, 1 cycle a day). E/W record of horizontal VolksMeter **Displacement** seismometer from 17th April 2015 to 4th June 2015 .

The ragged appearance of the record involves granular properties of the Earth; that are responsible for discontinuities. These occur during times of restructuring of material under the influence of various mechanisms—such as tidal force, solar radiance responsible for expansion/contraction, barometric pressure changes, oceanic tides etc. The magnitude of the fluctuations decrease with depth. Since the pier of TPSO is eight meters underground, influence of the tidal field on the pendulums of the VolksMeter can still be clearly observed. The same is not true of an instrument located on the surface of the Earth. Seismologists usually refer to this difficulty as deriving from the adverse influence of the diurnal thermal signature (DTS).

2.5.2. VolksMeter E/W case showing response to Earth tide quadrature cycle of 7.3 days (Cont).

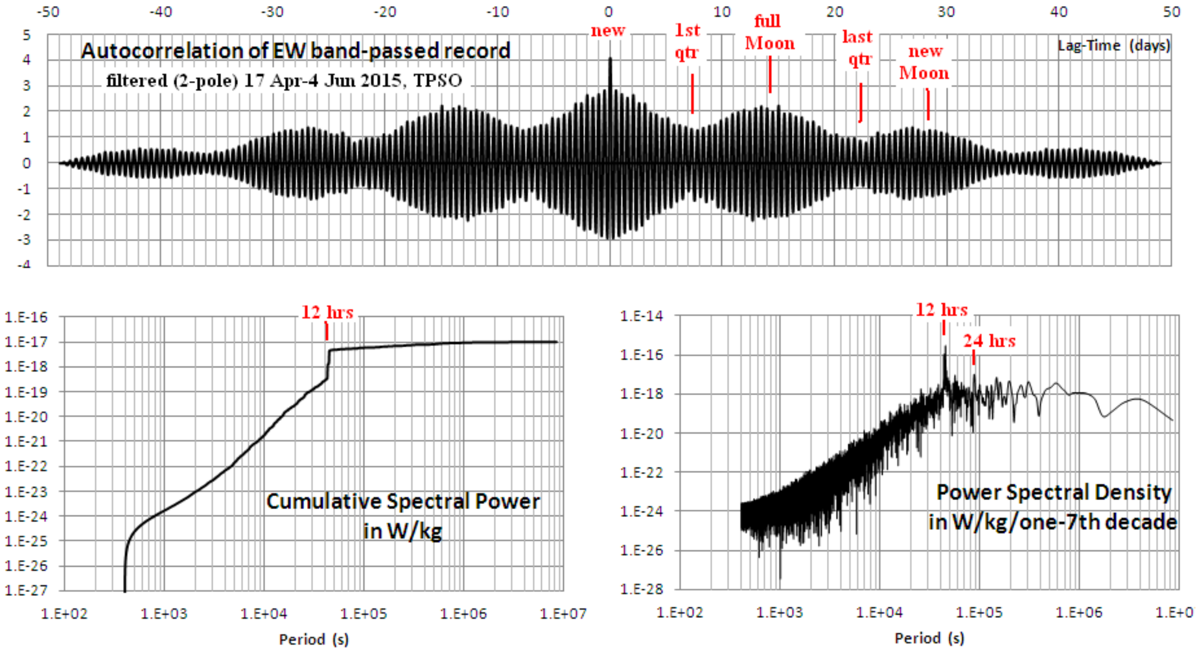


Fig. 2.5.2(c). Autocorrelation of band-pass filtered 2 pole. E/W record of horizontal VolksMeter **Displacement** seismometer from 17th April 2015 to 4th June 2015 .

Indicated upon the autocorrelation chart commencing at zero time, is the time of the New Moon (greatest gravitational influence upon the crust of the earth), the time of the 1st Quarter moon, the time of the Full Moon, time of the Last Quarter Moon, and the time again, of the New Moon.

As can be seen from this E/W case, for the recording period from the 17th April 2015 to the 4th June 2015, the variations in amplitude of the Earth tides is substantial. It clearly shows minima at ± 7 days and ± 22 days, in accord with the lunar quadrature cycle.

In addition, in the Power Spectral Density Chart of Fig. 2.5.2(c). being Watts/kg/one-7th decade, the 12 hour Earth tide and the 24 hour Earth tide spectral lines are clearly evident.

2.6. Grotta Gigante response showing the Earth tide quadrature cycle of 7.3 days.

The Grotta Gigante horizontal **Displacement** pendulous instrument at Trieste, Italy, is the only existing instrument to have recorded four out of five greatest earthquakes in the recent 50 years, allowing an absolute amplitude comparison between these events. The pendulums are of some 95 metres length, and of Zöllner construction having a period set at 360 seconds. As such the Grotta Gigante record shows not only the 12½ hour semi-diurnal, the 24 hour diurnal, the 7.38 day lunar quadrature cycle and the lunar monthly cycles, but also shows the lunar yearly cycle and shows the lunar 18.5 year cycle due to nodal regression of the lunar orbit.

http://www.researchgate.net/profile/Carla_Braitenberg/publication/236655991_The_Grotta_Gigante_horizontal_pendulums_-_instrumentation_and_observations/links/00463518b67de37d45000000.pdf

As such the Grotta Gigante is an ideal instrument against which to compare the capabilities of the horizontal VolksMeter **Displacement** seismometer to record Earth tides.

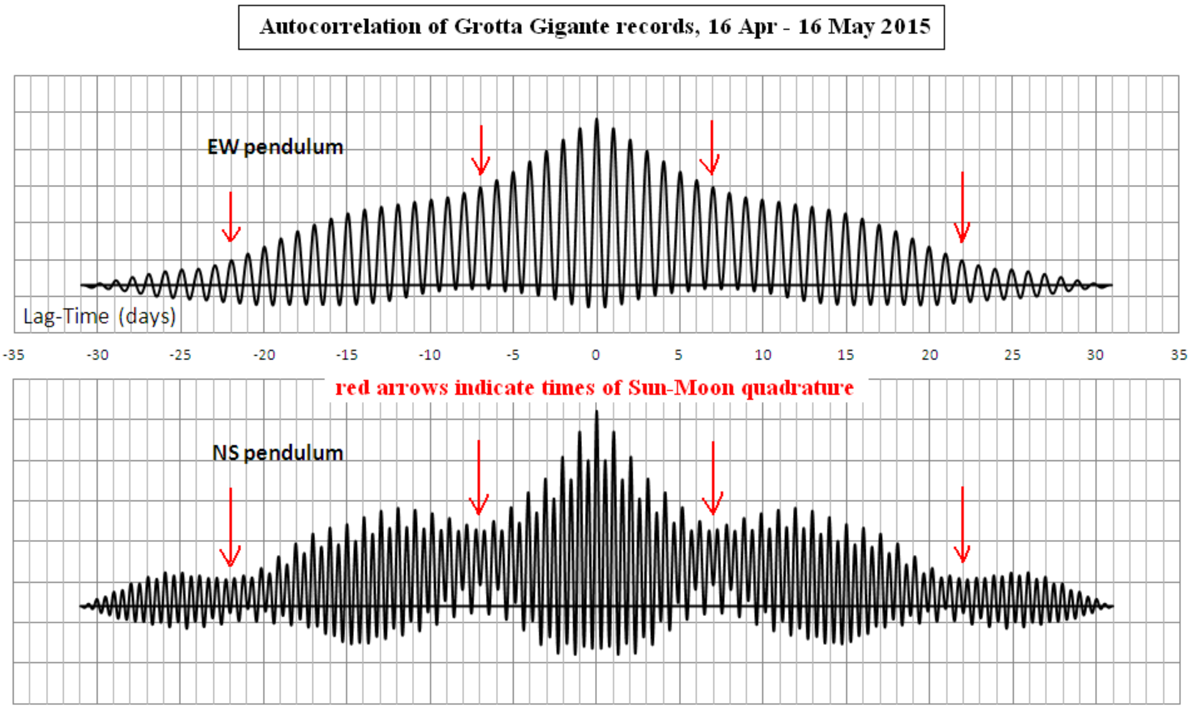


Fig. 2.4.1. Autocorrelation of Grotta Gigante record for period 16th April 2015 to 16th May 2015.

In both cases the Grotta Gigante records for this period, show the (relative) minima of a given autocorrelation occurring, as expected theoretically, at ± 7 days and ± 22 days, which correspond to times in the interval mid-April to mid-May; that the Sun and Moon were at quadrature (angle between them being 90 degrees).

The Grotta Gigante horizontal **Displacement** instrument thereby confirming during the recording period mid April 2015 through to mid May 2015 that the horizontal VolksMeter **Displacement** seismograph is shown to be especially sensitive to the 12 hour (semidiurnal), 24 hour (diurnal) and the 7.38 day (lunar quadrature) cycles.

2.7. Further Earth tide research at TPSO.

We have demonstrated the respectable capabilities and response of the horizontal VolksMeter **Displacement** seismograph over a wide range of periods from less than a second to Earth lunar quadrature cyle of 7.38 days.

This demonstrated capability is the basis for confidence in using the horizontal VolksMeter **Displacement** seismograph for further research into Earth accelerations/Tilt having periods greater than 1,000 seconds, being the ever present “hum”, the ever present eigenmodes of the Earth.

Evidence from previous studies using a single channel horizontal VolksMeter **Displacement** seismometer (and its predecessor) strongly suggests that there is significant benefit to be gained from improved measurements of acceleration/tilt with periods exceeding 1000 seconds. It is hoped this further experimental effort at TPSO will assist in gaining a better understanding of the granular crustal physics that influences our planet before earthquakes and so facilitate the elusive quest for meaningful earthquake forecasting.

A recent publication suggests the possibility for at least one form of synergy between theory and experiment related to this cause ["Prediction of catastrophes: An experimental model", by R. Peters, M. LeBerre, and Y. Pomeau, Phys Rev. E 86,026207 (2012)].

Bonafede – et al., 1983 reported that certain very long period perturbations preceded a M6.4 earthquake located 60 kms away from the Grotta Gigante instrument.

> *“Starting from 1973 a new kind of observation was made which initiated with a sudden permanent deflection of some msec in both components After this deflection the pendulums started to record perturbations which lasted for several hours. The number and duration of the perturbations increased between 1973 and 1976 when they suddenly disappeared with the M6.4 May 6th, 1976 Friuli earthquake (Zadro, 1978). The observations were interpreted as very long period elastic preseismic waves generated by aseismic slip on a fault neighbouring the main fault of the 1976 event.”*

Koshun Yamaoka, a scientist at the Earthquake Research Institute of the University of Tokyo, states.

> *"We believe that earthquake prediction is possible.”*

http://ngm.nationalgeographic.com/features/world/asia/japan/earthquake-text/4

Never the less, earthquake prediction is presently very long on talk and hype, and very short on facts.

But it is without doubt, research into 1,000 second and longer period accelerations/tilt will greatly enhance our understanding of the granular physics that influences our planet before earthquakes.

It is planned to install a Streckeisen STS-2 at TPSO.

Though they differ greatly in a variety of ways, the most significant contrast between the renowned Streckeisen STS-2 **Velocity** seismograph and the horizontal VolksMeter **Displacement** seismometer involves mode of operation.

2.7. Further Earth tide research at TPSO (Cont).

This proposed detailed study into Earth accelerations greater than 1,000 seconds, is designed to capitalize on benefits derived from a learned understanding of the following important difference.

The Streckeisen STS-2 **Velocity** seismograph provides unparalleled performance for earthquake detection. Its (capacitive) sensor is supported by state-of-the-art electronics (as well as mechanical superiority) to work with **Velocity**, the time derivative of inertial mass displacement, relative to the case of the instrument. It employs force feedback to keep the spacing between sensor plates 'constant'.

The horizontal VolksMeter **Displacement** seismometer does not employ force feedback; and its output is not proportional to **Velocity** being the time derivative of mass displacement, but rather the output of the horizontal VolksMeter **Displacement** seismometer is directly proportional to **Displacement** itself.

Like the Streckeisen STS-2 **Velocity** seismograph the horizontal VolksMeter **Displacement** seismometer also uses state-of-the-art electronics (Analog Devices AD 7745/6 chip) involving capacitive to digital conversion.

But in the horizontal VolksMeter **Displacement** seismometer the AD7745/6 chip is naturally integrated with the Symmetric Differential Capacitive (SDC) sensor [US patent No. 5,461,319 held by Peters] operating on the basis of area-variation, rather than gap-spacing to directly measure mass **Displacement** that is directly proportional to long period acceleration and/or tilt of the Earth.

This <u>fundamental difference between the two instruments</u> is responsible for two very different frequency regimes of optimal performance.

The Streckeisen STS-2 **Velocity** seismograph having a higher frequency regime of optimal performance as compared to the horizontal VolksMeter **Displacement** seismometer having a much lower frequency regime of optimal performance right down to D.C. or permanent tilt.

These two optimal performance regimes of the both instruments, are separated naturally in frequency, but are highly complementary in their cross-over region. Such complementarity has not been previously used to advantage.

Placed on the same pier, it is expected that careful analysis of synergetic data from the pair of instruments will advance a variety of geoscience causes. Because it is finally becoming a burgeoning field of science, new insights into the influence of the granular dynamics of our planet are certain to be realized.

2.8. Summary Part 2.

The demonstrated ability of the horizontal VolksMeter **Displacement** seismograph to competently record Earth Tides, up to the 7.38 day long lunar quadrature cycle, whilst housed in a temperature stable but extremely noisy seismic vault, is outstanding.

With the horizontal VolksMeter **Displacement** seismograph shown to be competent in recording earth motions with periods longer than 1,000 seconds then this will facilitate studies aimed at advancing a variety of geosciences causes.

Truly the VolksMeter is the “VOLKS” seismograph, the people’s seismograph.

End.