Posthole Seismometer Installation, Performance, and Reliability in Challenging Environments

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SUMMARY

Posthole seismometers allow flexible deployment and therefore expanded coverage and densification of networks in wet and challenging environments. We present techniques for deployment in various environments: marsh, forest, glacier, permafrost, seasonal freeze/thaw environments, hard rocky soil, and different soil thickness ranging from deep basin sediments to exposed bedrock. Statistics so far indicate reliability of buried posthole seismometers is similar to equivalent surface-version seismometers in vaults.

Marsh

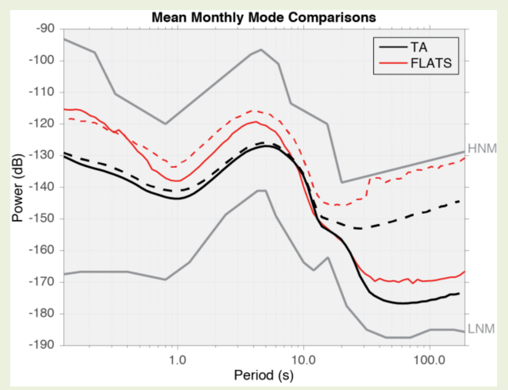
Instrumenting riverbanks, marshes and other wet saturated soils such as volcanic calderas with posthole broadband type sensors is now possible without elaborate water proof enclosures or diving bell type systems which are rarely effective at keeping a vault style sensor dry. Instrumenting in these areas with vault type instruments could likely lead to sensor and data loss. Posthole type sensors solve the water and instability issues along with reducing the logistics needed to successfully deploy arrays in these environments. Auger a hole and emplace the sensor in sand whether the hole is filled with water or not.





Photos courtesy Carl Tape, New Mexico Tech Staff and Nanometrics staff

FLATS experiment in the Nenana Basin, AK. The majority of the sensors were deployed from a boat along the riverbank.

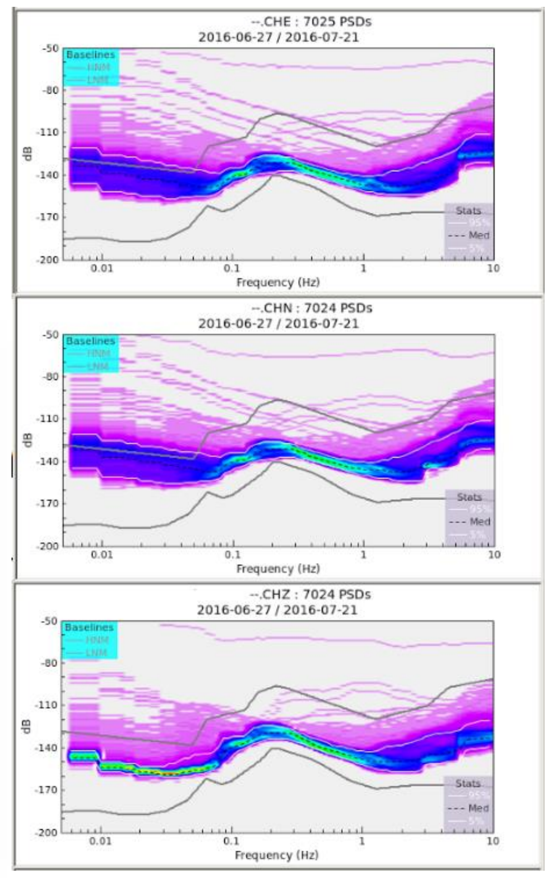


Beaudoin, et al (2016)

Forest

Temporary deployment by Nanometrics Oil & Gas Services for hydrofrac monitoring in forest in NE British Columbia. Access was by ATV. Trillium Compact Posthole seismometer was buried 0.5 m in shovel hole. Digitizer was housed in a plastic box with sufficient batteries for the duration of the deployment. Vertical noise floor is limited only by instrument self-noise plus microseismic background. Horizontal channels show some additional tilt noise due to settling of soil, with large initial tilt events reducing over time.


Photos courtesy Nanometrics staff



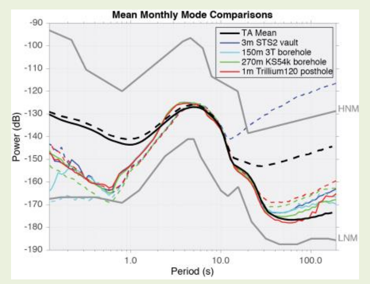
Glacier

Glaciers can have dynamic environments requiring sensors to have a higher tilt tolerance, immersion proofing to survive water ponding at lower latitudes and altitudes and extreme cold tolerance when located in high latitudes or altitudes. Installation of postholes is much simpler than traditional vault style instruments and has proven effective over 5 seasons and close to 50 Antarctic and Arctic deployments. Simply dig a 1-2 meter deep hole, compact the bottom and install the sensor. No need for logistically challenging enclosures to protect the sensors.



Photos, Rick Aster and New Mexico Tech Staff

Comparisons of instruments installed at the South Pole SPRESSO station, note the 1m deep posthole performance relative to deep cased borehole instruments.



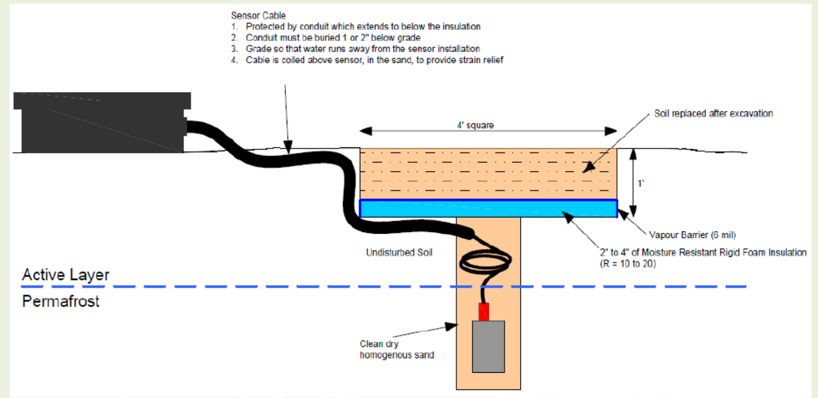
Beaudoin, et al (2016)

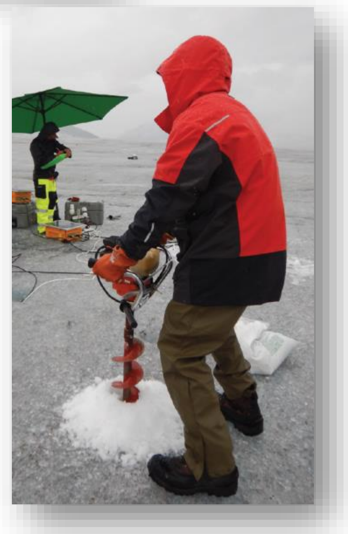
Permafrost and Seasonal Frost

An augur or an ice chopper can be used to cut a hole into permafrost. A layer of foam insulation can stabilize freeze/thaw activity so the sensor is not affected by frost heaving. The PDF plots at left show performance of such an installation at MMPY, University of Ottawa Mackenzie Mountain Station, Yukon, Canada. Near-NLNM performance can be achieved in solid frozen ground which behaves similarly to rock.

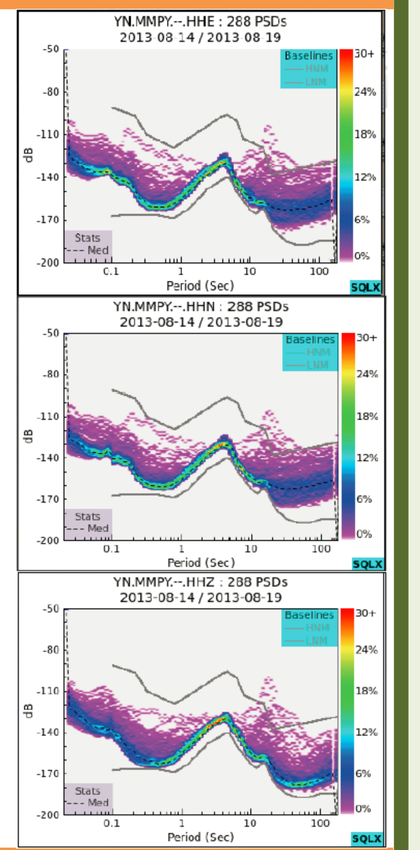

Ice chopper/ rock pry bar

Permafrost station diagram





Photos courtesy of GEOICE project and Nanometrics staff



Hard Rocky Soil

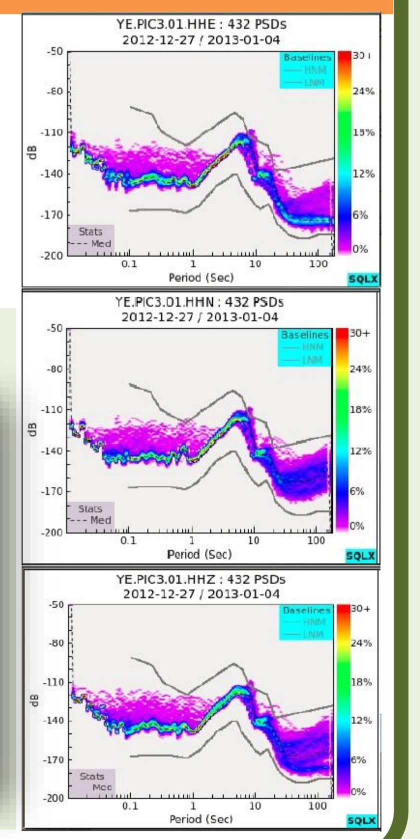
Simple hand tools can break up hard rocky soil, as at these sites in Alaska. Researchers needed carry only shovels and pry bars to quick-deploy instrument kits for a lightweight helicopter deployment at Okmok Caldera (August 2016) as shown below. A powered auger was used in rockier terrain at Poker Flat, PASSCAL Instrument Station YE.PIC3.01 – see data at left. Poker Flat had less than 1 meter of clay rich soils and broken rock overlying bedrock, so it was possible to place the sensor near bedrock, covered by less than 1 meter of material for insulation. This is an ideal situation for posthole deployment as shown by near-NLNM noise performance even on horizontal channels. Sweet, et al (2015)

Installation of T120PH by auguring through consolidated wind deposited soils above weathered bedrock at Poker Flat Alaska, USA

Rectangular hole cut/chopped with shovel in hard ground at Okmok Caldera, AK

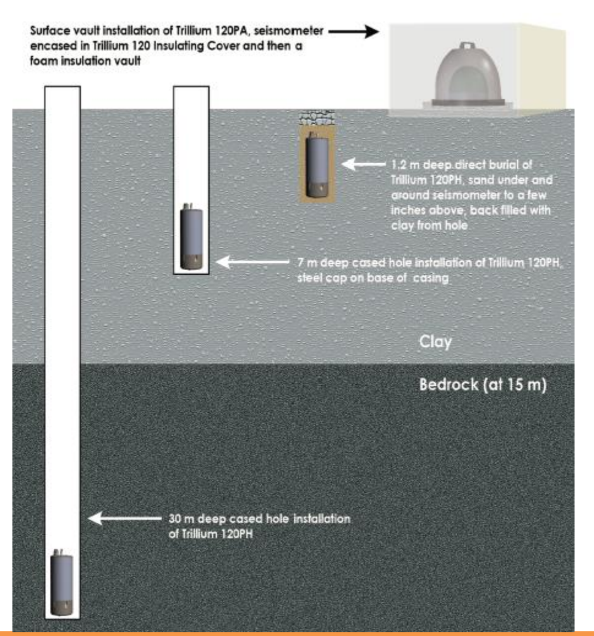
Alignment rod and compass for orientation

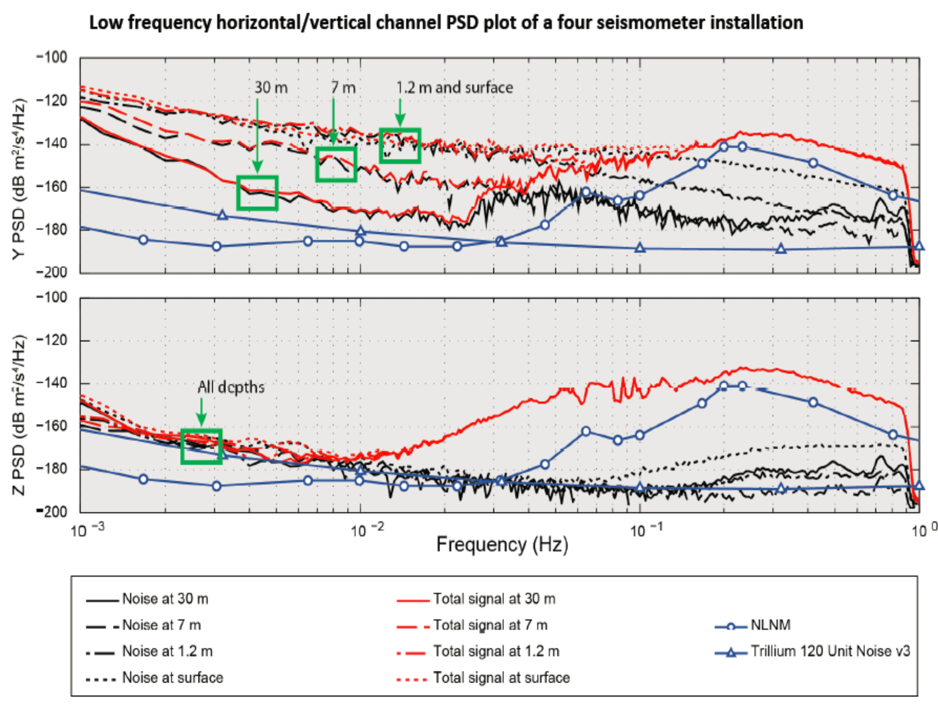
Photos courtesy of New Mexico Tech and Nanometrics staff. PASSCAL Poker Flat Tests and noise metrics from IRIS DMC



Deep Sediment

Noise performance improves with depth as shown in this experiment at Nanometrics, Ottawa, Canada.



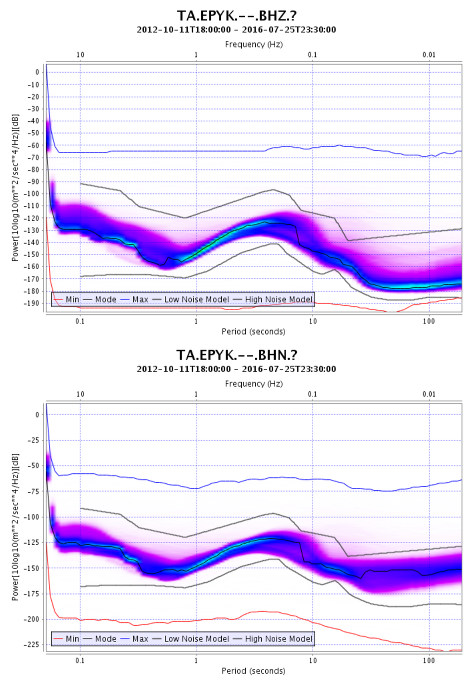


Exposed Bedrock

The TA (Earthscope Transportable Array) has installed postholes in shallow boreholes in exposed bedrock drilled with off the shelf coring tools when accessible by road and custom lightweight percussion drills when only helicopter or aircraft can reach the site. Coring and preparing the holes in competent bedrock can be completed in as little as 4 hours to depths of 2 meters. An example pictured here is in Eagle Plains, Yukon Territory Canada.



Photos and metrics from IRIS DMC and New Mexico Tech



Reliability Statistics

As of this writing, Trillium 120 Posthole has been in production for five years (2011-2016) so its long-term reliability can be compared to the equivalent vault sensor products Trillium 120P/PA. So far the average annual rate of out-of-warranty failures due to all causes including mishandling has been **0.6%** for T120 Posthole and **0.4%** for T120 P/PA. The difference between these failure rates may not be statistically significant given the small number of failures. We can conclude that both products have similarly high reliability (MTBF well over 100 years) despite the harsh deployment environments for posthole sensors.

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