LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Seismic stations implementation and improvements at Homestake

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Installation of seismometers at Homestake, December 2008.

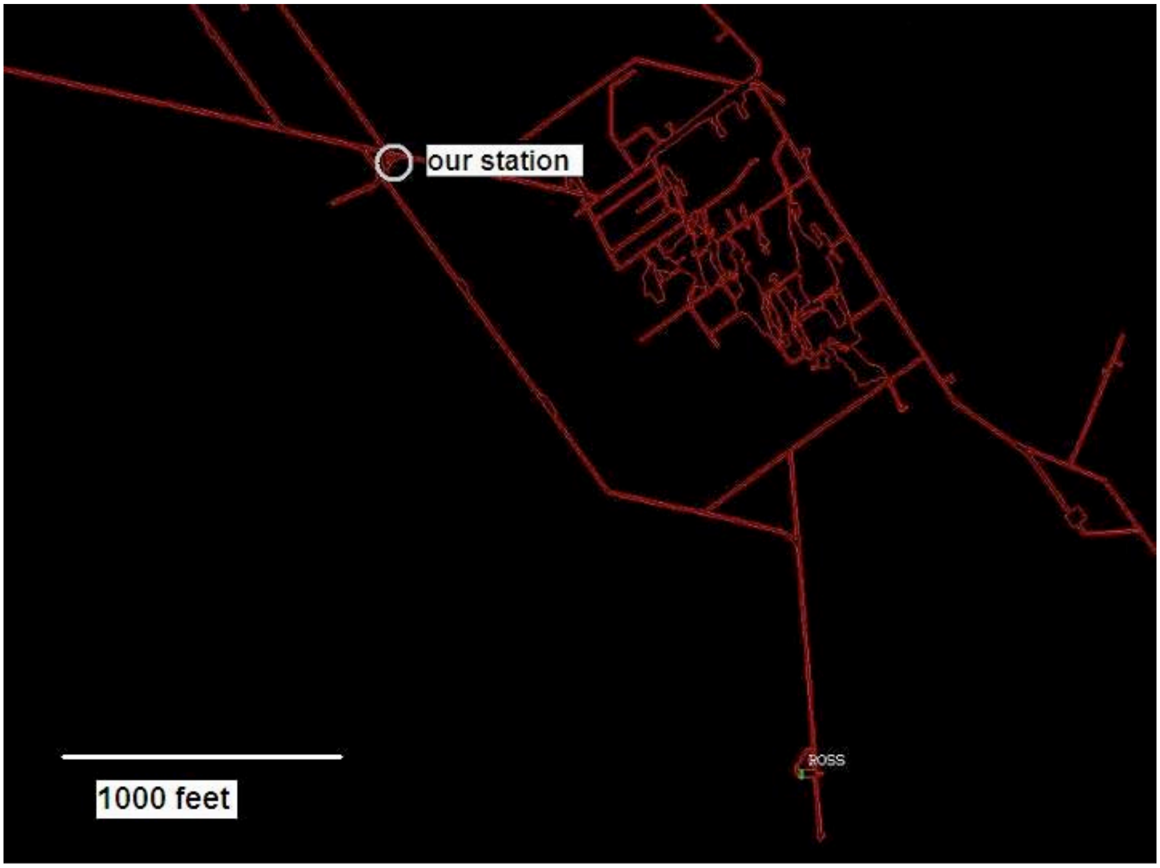
The Black Hills are snow covered with temperature that reached -15^{o}C. No way to move without chains.

Even waiting for the cage requires warm clothing. Down below it is warm and steamy as usual.

Developments at the 2000’ level, granite tiling.

The 2000’foot level site is our largest site, it was built on an existing wide and thick concrete platform, which was sounded to make sure that it was not hollow and well connected to the rock.

It is located at the junction between two converging tunnels, not ideal, but decently good.



Two double thickness foam walls were erected near the openings towards the two converging tunnels.

Back wall

Front wall.

The computer hut was built in front of the front wall.

This site can house several instruments (four for now) in a thermal acoustic foam box `1.5x1.5 m. It is used as a staging site, and for cross calibrating all instruments before installing them in different locations.

Improvements: installation of granite tiles.

We found in the preceding summer tests that mounting the accelerometers on flat, polished surfaces is important because of the fact that differential thermal expansion on a rough surface can change the instrument tilt and generate jerking motions.

We procured ¾" thick 36x36" square granite tiles, polished on one side, de-polished for tiling on the other. It is important though that the tiles are rigidly connected to ground to transmit the entire seismic motion.

We used "Rockite" fast setting, anchoring concrete for mounting the tiles to the existing concrete floor.

Granite Tile Installation Procedure.

Installation at the 2000' level.

We identified the positioning of the tiles next to the operational accelerometers, after lifting the foam box and the duvet.

We used a strong wire brush to brush away all dirt from the concrete surface until it became clear concrete color on the entire adhesion surface.

We scribed the area where to mount the tile, extending the scribing well outside the area, and test set the tiles

We prepared a semi-fluid concrete mix and spread some on the desired surface, forcing it into the old concrete with a metal spatula

We repeated the same on the tile rough surface, to guarantee full adhesion on the entire surface. We prepared a drop of semi-fluid mix at the center and applied the tile on it.

We then applied pressure until the mix oozed out from al sides, trying to keep the tile level.

The mix hardens very, very rapidly.

After 5 minutes we scraped out the excess mix with a wood spatula.

The first tile did not come completely level, because of inexperience (we had not prepared enough mix).

It was tilting a little less than a degree towards North.

For the second tile we measured more carefully the tilt of the existing concrete, used wood shims to maintain the tile level when setting and prepared much more mix.

The second tile came out as level as the bubble resolution (small fraction of a degree).

The Foam box was then put back in place.

Instrument installation at the 2000’ level.

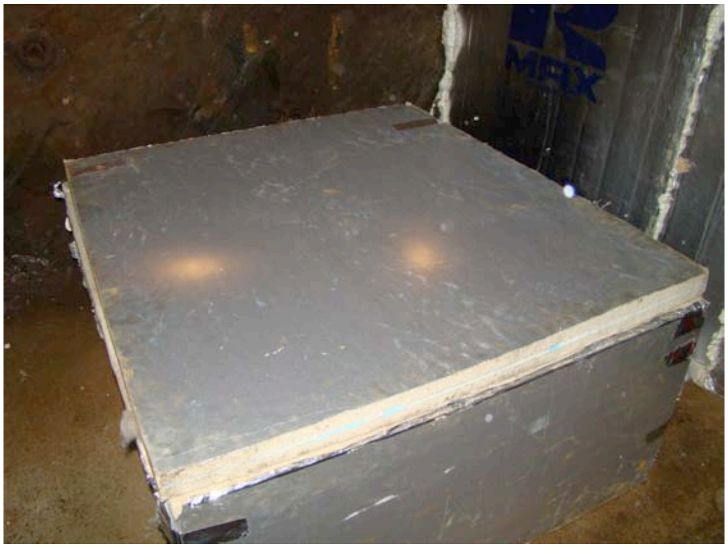
Back at the 2000’ level, after two days of hardening we installed the STS-2 and the Trillium 240 on the tiles, and mounted two new tiles at the previous location in preparation of the tests of the folded pendulum accelerometers.

Here are photos of the installation, accelerometers each in its thermal acoustic enclosure.

The thermal acoustic box is installed next (shown before closing).

and the duvet that keeps the ground isothermal and avoid convection.

Finally the thermal box is covered.

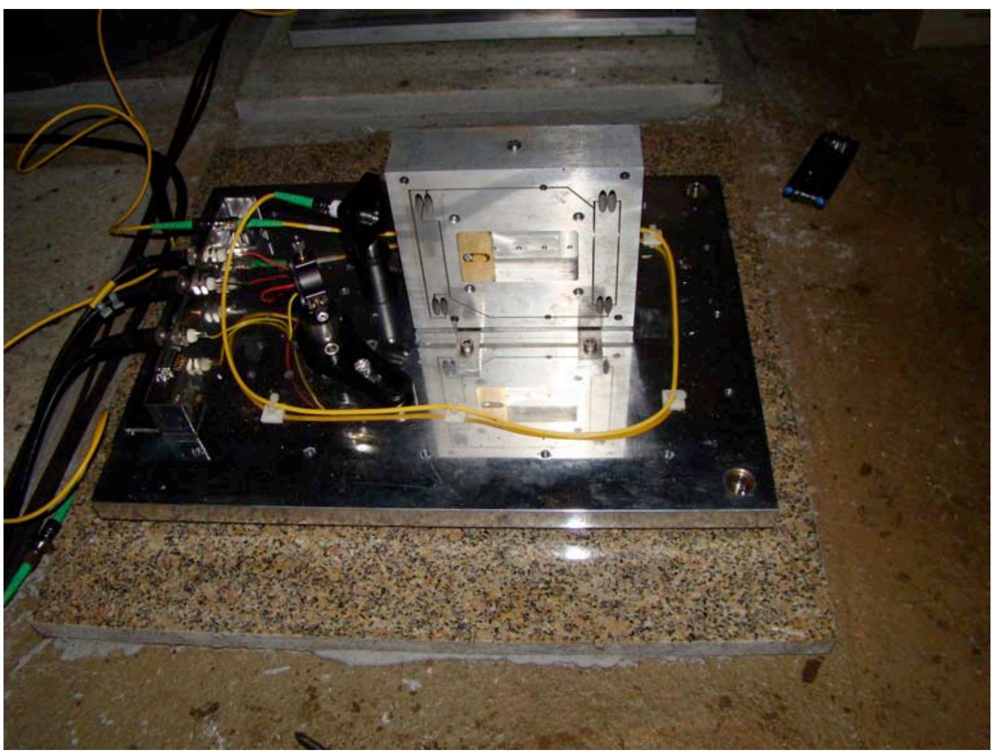


And the thermal acoustic hut is closed.

Data was then taken for two days in this configuration.

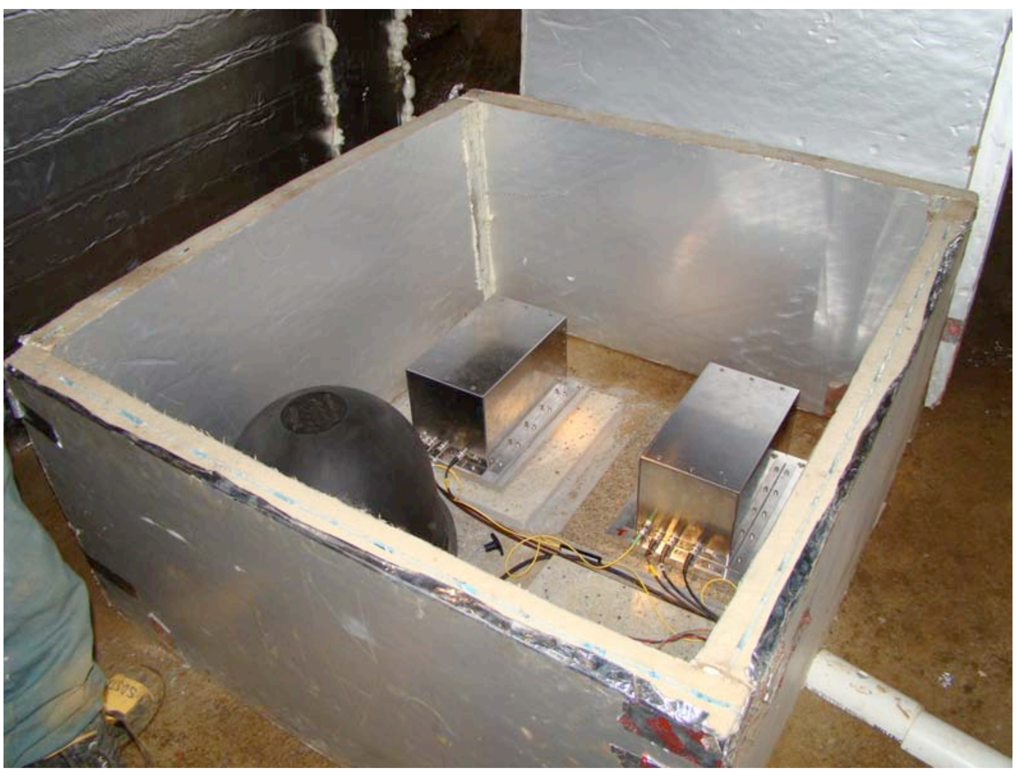
After two days we got the Salerno horizontal accelerometer prototypes ready and mounted them in the free pads, we also removed the STS-2 for installation at the 2000' level. First the two accelerometers get aligned.

and leveled.



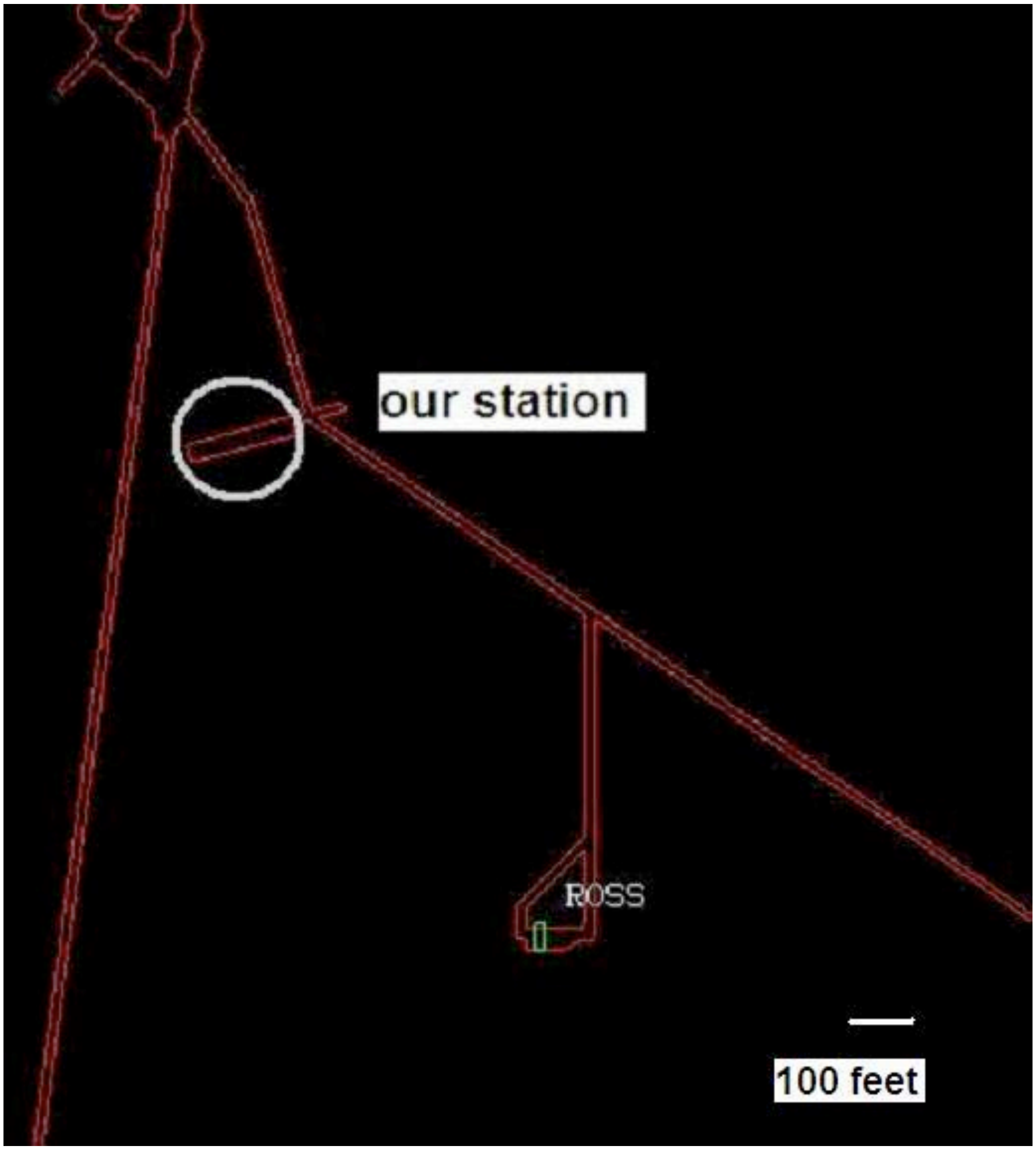
Then closed cabled and fine levelled

Then again the thermal acoustic box is lowered.



Duvet is put in, the box closed, the hut closed and data acquisition started.

Installation at the 800' level.

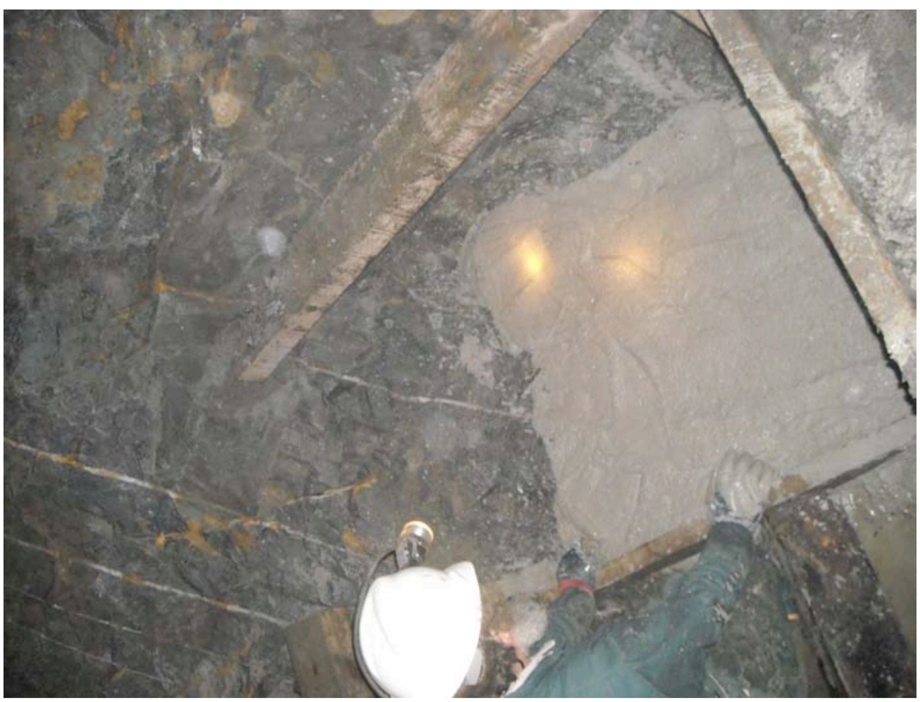


The site is particularly good because the instrument hut is at the end of an abandoned 30 m long, 4 to 5 m wide dynamite depot. We padded the strong entrance gate with Styrofoam panels, thus sealing the room and generating a large isolated lung. The tunnel itself is rather quiet. This is one of the best sites we developed

Outside view.

Inside view.

The 800’ level site had no concrete platform, the rubble making the floor of an old dynamite depot was excavated down to the rock, which was sounded to ensure solid contact. The rock was washed, concrete was smeared on the cleaned rock surface to ensure good adhesion, then more concrete was poured to form a ~ 1x1 m platform.



The instrument hut was then built around the platform, and the computer hut next to it.

The site was then abandoned while waiting for electrical power to be provided.

Two month later we returned to the site. We cleared the surface of the concrete pad that we had prepared in the summer.

We found that the surface is not quite as hard as expected. It is quite rigid but brittle. The wire brush manages to scrape out some of the grit from the concrete.

For the future w should not rely anymore with pre-mixes. We should stick to the old fashioned 1-2-3 Portland cement, washed sand, gravel mix for bulk and 1-2 Portland cement, washed sand mix for surfacing.

We followed the same procedure and mounted the single tile again level within the sensitivity of the bubble.

Note the small amount of seeping water found next to the slab. The station is much more humid than the 2000' level, but less than the 300'. The good thing is that we had only minimal seeping.

After a few days of hardening we returned to the 800' level to install the STS-2 o the tile and inside a foam thermal acoustic box.

Like in the other cases it was mounted into its own thermal shield. Next to its weather station.

The cabling pass through the thermal acoustic box,

from the sensor hut to the computer hut

The crew bringing power to this site accidentally broke our internet fibers

We did switch to the fiber reserved for timing, not yet in use, thus restoring connectivity from the shaft to the site. The 800' level site will be fully operational as soon as internet connection down the shaft will arrive (any time).

Installation at the 300' level

This was the first site we developed while we were waiting for access to deeper levels, it is along a noisy tunnel.

It is also quite wet, with water seeping from the ceiling. It is built on an old pumping station platform. It is a good baseline of the seismic noise close to the surface. Substantial work was done during the summer to build the huts and divert the water.

Instrument hut.

Computer hut.

Returning to the 300’ level we found that the instrument hut is substantially drier than when we left it in the summer (probably the water froze above us, at the surface it is ~-10^{o}C), but still the wettest of the three, also it is much colder, although the water was not freezing yet.

The super-elevated concrete pad in the thermal-acoustic box that we prepared for the instruments is quite dry, though.

The tile barely enters in the box and the surface of the pad, although flat at the center, has ridges at the periphery that require ~ ¾” thick filling with concrete mix.

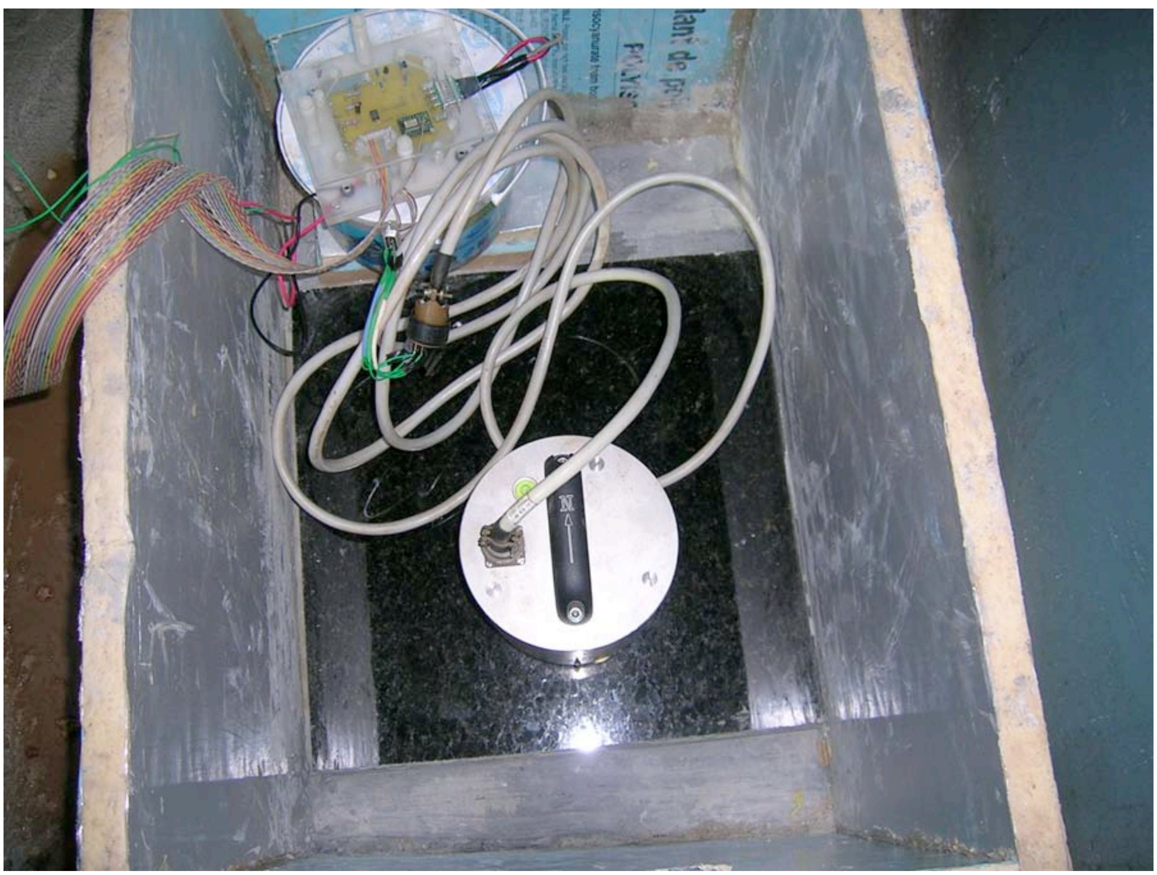
We prepared much more mix, made a big cake at the center, put the tile on it and pressured it to bring it horizontal and having mix coming out on al sides. On two sides the box provided natural damming for the oozing out of the mix. Mostly it came out on the other 2 sides.

After bringing the tile to horizontality we noticed that the mix was started flowing away (the ¾” thickness was too much to impede flow), we pushed it back in with the wide spatula and dammed it with wood sticks to keep it from generating voids.

We also noticed that because of the low temperature the mix was taking much longer to congeale. Because of this the tile ended up with a small tilt, not quite within the resolution of the bubble.

The tile and Guralp seismometer fit nicely in the small thermal box at this level.

Note the weather station next to it.



It may be worth noting that in all stations we have a completely separated box for the computers and power supplies. The box provides thermal separation from the instruments and acoustic isolation for the computer cooling fans.

Future stations, the 4100’ level.

Exploring the 4100’ level we found and discarded a few noisy sites, made unsuitable by lots of rushing water nearby. We then explored a different tunnel, which rapidly became silent and suitably dry. It is very promising. We almost arrived to a small explosive depot, slightly bigger than the one below, but we were stopped by a fallen boulder.

Also 20 Granby wagons were in the way (not a big deal even if we were to turn around them. We were told that the tunnel can be scaled to safety, and maybe the Granby train removed by the time that we would show up with a fourth sensor.

The place is very promising for a fourth seismometer to complete a vertical array of sensors with roughly doubling depth each station (300’, 800’, 2000’, 4100’).

This would make for a very relevant seismometer array to study the attenuation of surface waves with depth, and the reflection or pressure and shear waves from below as they get close to the surface.