Considerations for a geophysical section of the ANDES laboratory

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1 Requirements

The small-signal detection capabilities of BFO (Black Forest Observatory) are taken as a reference. BFO is one of the most sensitive installations in the global network. It provides recordings of ground acceleration, gravity variation, and rock deformation, and other observables. Where possible, the site conditions of the AGS (ANDES geophysical section) should support observations of global signals at a similar level. The instrumentation of AGS will not be identical to that of BFO and probably only a subset of instruments will be installed initially. However, premises shall be designed to supportive for a variety of possible future installations.

The smallest detections threshold in terms of level of acceleration currently is achieved for vertical component signals in the period band of Earth' free oscillations (Berger et al. 2004; Peterson 1993; Zürn and Wielandt 2007). The following conditions in the period band of Earth's free oscillations (signal period of about 100 s to 3600 s) are mandatory to allow current instruments to detect signals at this level (Forbriger et al. 2010): Temperature variation within sensors must be less than $\pm 1\,\mu$K. Pressure fluctuations in the sensors must be less than $\pm 10^{-5}$ hPa. Variations of magnetic field in the sensors must be less than $\pm 10^{-2}$ nT.

The absence of such variations is achieved by a proper casing of the sensors as well as careful local shielding (Forbriger 2011). These measures however are useless, if local site conditions are not appropriate and expose the installation to too large variations of these physical quantities.

For sensitive short period recordings the level of artificially generated ground vibrations must be kept small. This is most effectively achieved by placing the instruments at the largest possible distance to local, artificial sources of ground vibration.

2 Design considerations

2.1 Shielding

Good temperature and pressure stability is most effectively provided by passive shielding. Active control always comes at the risk of residual control cycles in the ambient parameter.

Overburden provides excellent thermal shielding. Air-locks additionally prevent heat transport which would result from large-scale exchange of air with the exterior. Air-locks have proven effective means to stabilize air-pressure due to their low-pass effect. At BFO air-locks effectively are first-order low-pass filters with eigenperiods of 36 h to 50 h. To obtain large filter periods excellent seals of the doors (resistance) as well as a large volume behind the air-lock (capacitance) are required. The 200 m long gallery will serve as the low-pass' capacitance.

Air-locks must provide a feedthrough for signal cable, optical fibres, power supply cables, possibly water circulation (for active means of cooling) and must provide siphons to remove immersive water.

2.2 Fissure water and humidity

Cracks in the rock are expected to leak water into the gallery and the vaults. The gallery shall be slightly ascending, such that water is removed passively by down-hill flow. Air-locks must be equipped with siphons. The floor in the galleries requires a gully. Instruments will be protected against high humidity by application of a desiccant (Silicagel).

2.3 Protection against local sources of noise

Most significant local sources of noise probably will be the traffic tunnel at short signal periods (frequency of a few Hz) and ventilation systems at long periods (a few minutes to hours and larger). The short period sensor (to be located in vault J in Fig. 1) thus should be at the largest possible distance to the traffic tunnel and machinery in the other physics laboratories. This consideration defines the optimal location and azimuth for the gallery. The long-period noise (potentially affecting the sensors due to temperature variation and air pressure fluctuations) shall be reduced by the air-locks and passive thermal shielding.

2.4 Ambient temperature

Ambient temperature (without air-conditioning) is expected to be at least 50 °C. Active temperature control shall be avoided wherever possible. Since standard electronic components are only rated up to 60 °C or 70 °C, ambient conditions must be checked after premises being finished. Additional air-locks in the gallery and between gallery and vaults shall allow for selective operation of cooling or air-conditioning devices, where needed. If necessary, the data acquisition systems for example, could be installed in a moderately air-conditioned gallery, while the vaults remain passively shielded.

Superconducting gravimeters (SG) require cryocoolers which are rated only to 28 °C (or a maximum of 35 °C with a 10 % loss of efficiency). Means of active air-conditioning must by considered for these instruments. In particular the waste heat of the compressor system must be removed. The compressor vault and the SG-vault for this reason are close to the entry of the gallery.

If air-conditioning is required in parts of the premises, means to transfer heat (e.g. by water circulation) through the air-locks must be provided.

2.5 Coupling and wall plaster

Instruments must be well coupled to the ambient rock. Broad-band sensors must not be bolted to the rock's surface. They should be installed on a horizontal, flat, clean surface. Naked rock surfaces are most appropriate if they are not disturbed by fissures, where any small (even not properly visible fissure) may result in differential vertical displacements which cause unacceptable noise on components measuring horizontal acceleration. If there is a risk of such fissures, proper seismic piers made of concrete should be preferred.

The walls and the ceiling not necessarily require wall plaster. The type of surface for walls and ceiling will depend on considerations regarding water leakage and whether instruments shall be mounted on the walls (e.g. borehole tiltmeters clamped to the wall).

2.6 Accurate timing

Signal digitizers require an accurate clock which controls the sampling process. Accuracy is required since observations must be compared with observations at different locations on the globe on a common time scale. Precision of the time is required, since a jitter in sampling time directly translates into signal noise. Highly accurate and precise observatory clocks are available on the market. In the long run they must be disciplined by an external time source. GPS is a common option for seismic recording systems but is unavailable in subsurface installations. It is therefore necessary to transmit timing signals received at the Earth's surface to the underground site. Probably the other physics laboratories also require accurate timing and the necessary signals can be obtained from the installations there. If not, extra means of transmission must be considered.

In order to have no consequences for the effective dynamic range of the digitizers the time jitter Δt should be

$$\Delta t < \frac{T_{\mathrm{Ny}}}{2\pi D} \tag{1}$$

where D is the dynamic range of the recording system and T_{Ny} is the Nyquist period. For the state-of-the-art recording systems with 24 bit of dynamic range Δt shall be smaller than 0.32 ns at a sampling rate of 100 Hz and smaller than 320 ns at a sampling interval of 10 s. This is most effectively guaranteed be high-precision clocks. The means of synchronization with external time sources (like GPS) must not cause a disturbance which could deteriorate the clock's precision.

2.7 Emergency power

All instruments and data recording systems require continuous and uninterruptible power supply. For the cryocooler of the SG and the temperature and dewar pressure control system of the SG, uninterruptible power is vital. If the other facilities in ANDES cannot provide uninterruptible power for AGS, a dedicated diesel power aggregate must be installed in a separate room (with effective means to lead away exhaust fumes).

2.8 Sanitation and accomodation

At campaigns operators and scientists will have to stay at the facility for severals days. Basic accomodation and sanitation facilities must be provided near the installation.

3 Premises

A draft of the premises is shown in Fig. 1. The different compartments and their dedication are:

A — Storage: A utility location to store unused equipment, transport packaging, etc.

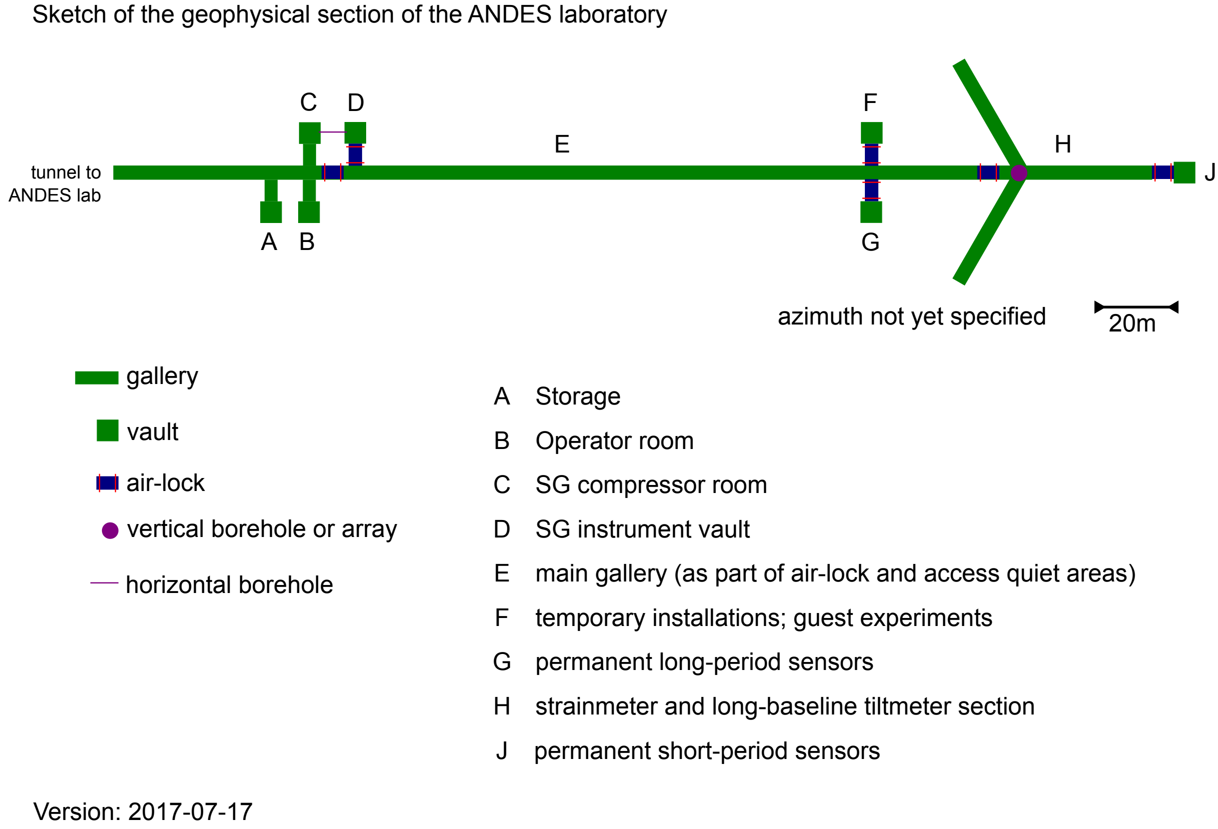

Figure 1: Draft of the gallery and the vaults for the geophysical section of the ANDES lab. The azimuthal orientation shall be such that the vault J is at largest distance to the traffic tunnels and the other physics laboratories.

B — Operator room: A room to host data storage systems and operator screens. A workshop providing electronic and mechanical tools and a small electronics laboratory should be located here too.

C — SG compressor room: The SG compressor room is located in front of the first air-lock. The physical section of ANDES is expected to be air-conditioned, such that waste heat of the compressor (about 1.5 kW) can be lead away to the air-conditioned part of ANDES. The SG compressor room and the SG instrument vault are connected by a horizontal borehole for the high-pressure He-hoses. This borehole must be sealed after installing the He-hoses. This location (where ground vibration might be generated by the compressor) is at largest distance to the vault J for the short-period sensors.

D — SG instrument vault: The SG instrument vault is placed next to the first air-lock. This way the He-hoses need not be longer than 10 m while at the same time the compressor room can benefit from the air-conditioning of the exterior and the SG instrument vault can benefit from the air-lock with the large gallery volume behind the air-lock. The SG instrument vault is separated from the gallery by an air-lock to allow for a moderate active cooling without affecting the ambient conditions in the gallery. Safety mechanisms must be considered, which can handle a catastrophic failure of the dewar system which would result in a rapid increase in vault pressure and a rapid drop in oxygen percentage.

E — main gallery: The main gallery serves two purposes. First it allows the short period instruments (vault J) to be placed at the largest possible distance from local noise sources. Second it is part of the primary air-lock and guarantees the low-pass to be effective at large signal period due to its volume.

F — temporary installations; guest experiments: A separate vault is provided for guest experiments. This way maintenance of the guest experiments will have the least negative effect on the permanent recordings.

G — permanent long-period sensors: Long-period sensors (primarily broad-band seismometers) require protection by the primary air-lock together with the large volume of the gallery. They, however, do not require the largest distance to local sources of short-period noise. The location at the end of the main gallery thus is appropriate for their installation. Again, this vault is separated from the gallery by an air-lock in order to allow for a moderate active air-conditioning of the gallery if it should turn out to be unavoidable.

H — strainmeter and long-baseline tilmeter section: This section of the gallery and two smaller arms (each at an angle of 120 °) shall house strainmeters and tiltmeters. Three long-baseline half-filled fluid tiltmeters, each in one of the three arms, provide means to record long-period to DC tilt. Installing three of them provide means of reduncancy which will be required to estimate the order of magnitude of cavity-effects. Three strainmeters, one in each arm, together with an array of borehole strainmeters in near-vertical boreholes aligned to the edges of a cube-corner, at least theoretically, can provide recordings of the full strain-tensor. This part of the gallery is isolated from the main gallery by an air-lock. If moderate air-conditioning of the main gallery should be unavoidable, this still cannot be tolerated at the location of strainmeters.

J — permanent short-period sensors: The short period sensors (short period seismometers) shall be located in a separate vault at the most distant end of the gallery. This way, hopefully, the locally generated short-period noise (caused by traffic in the tunnels and machinery in the other laboratories) has decayed to a tolerable level at the instrument's location.

4 Final remarks

The considerations outlined here might not be complete and are still under discussion. Open issues identified here in particular are:

- Can accurate timing be obtained from facilities in the physics lab?
- Can emergency power (of about 10 kW to 20 kW) be obtained from the physics lab? **If not, an additional room will be required.**
- Are sanitation and accomodation facilities available in the other ANDES facilities and can the be used by operators of the geophysical section too? **If not, an additional room will be required.**
- How much of active cooling and air-conditioning will be unavoidable and how can this be provided without deteriorating data quality?

References

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