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Concise caption describing the content of the file:

ESM_01.pdf file contains six pictures and short explanations about the Test design and the site preparation before the drop tests.

Contents

In the main text, when explaining the Fig. 2, we define the exclusion area (for safety considerations) by means of two angles: the lateral spread (horizontal semi-aperture, β) and the runout or reach angle (α). In principle, we stake out both angles from the release area: β=30º, right and left from the average dip direction (Fig. ESM01-1); α=30º, below the horizontal.

The adequate values for these angles (β, α) depend on the site characteristics. For instance, in Volkwein et al. (2017) field test, a lateral spreading of 14º and a "shadow angle" of 28.5º was registered after 111 drops. In case of any doubt, a trial 3D simulation with average tentative parameters can be performed. In 2017, one of these simulations was performed with the code RockGIS (Matas et al., 2017, 2020) for the Test 4 site (Fig. ESM01-2). The simulated stopping area differs laterally from the standard exclusion area due to the change in direction exhibited by the main slope in its lower half. In general, during the Tests 1-4 execution phase, we verified that β=30º and α=30º were safe enough for the equipment (cameras, targets, and so on). An extra distance for personnel should be adopted, along with standard protective measures.

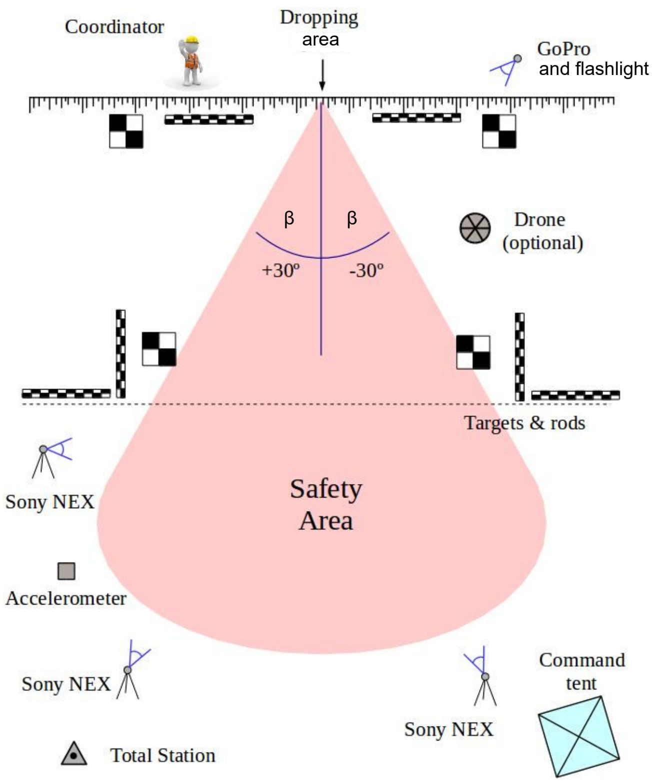

Figure ESM01-1. Ideal layout for field tests 1 to 4: plan view with the planned equipment.

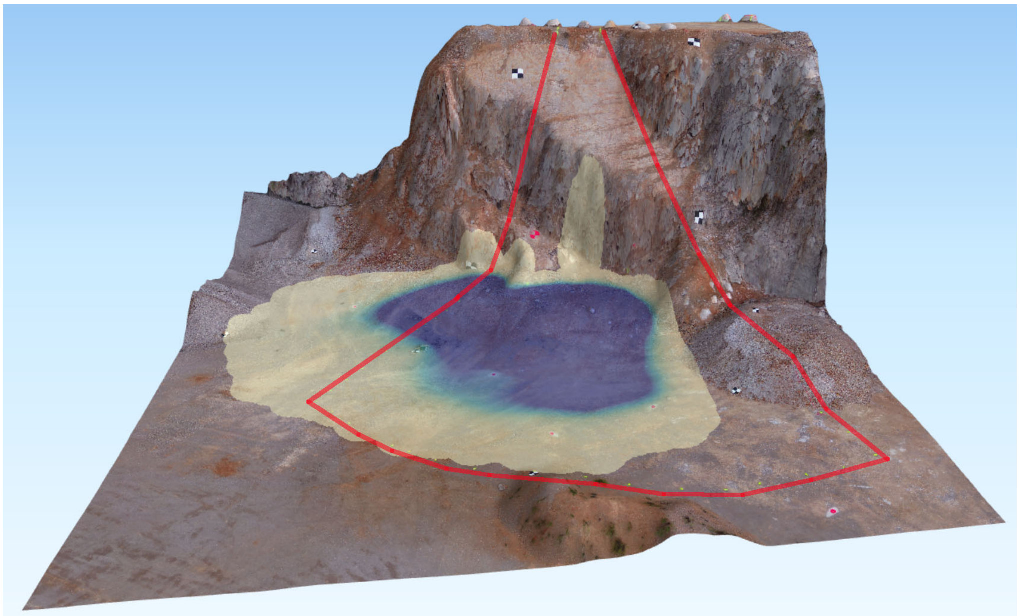

Figure ESM01-2. Exclusion area for the Test 4 topography. The background image is a drone 3D model perspective. In red line, the standard area (lateral spread β=30º, reach angle α =30º). Both angles were set out from the crest of the slope, β right and left from the upper half dip direction. The area shadowed in violet encloses the 90% of the detention points as simulated in 2017 with the code RockGIS (Matas et al, 2017, 2020) with average tentative parameters. The lateral disparity between the two contours was confirmed in the field during the test.

In Fig. ESM01-3, the blocks ready for launch in the Test 3 storage area can be appreciated.

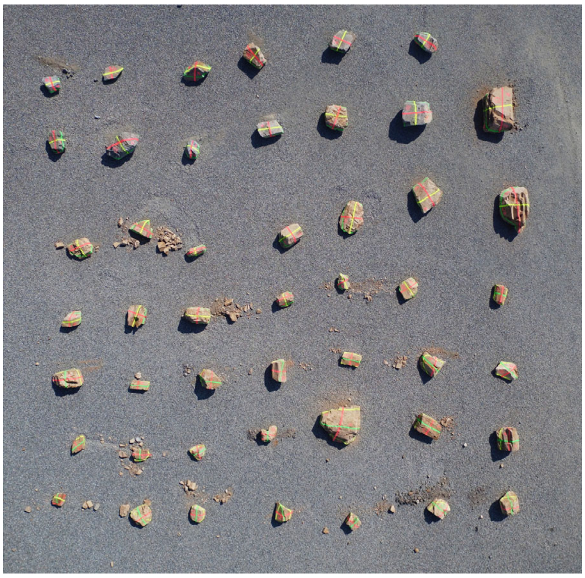

Figure ESM01-3. Test 3 site, storage esplanade: general drone view of the 48 dacite and granite blocks ready for launch. The picture covers an area of 50 x 50 m approximately.

During the Test 3 preparatory work, we were able to characterize some blocks with an ultrasonic sclerometer, Pundit type, 50 KHz, Fig. ESM01-4.

Figure ESM01-4. Test 3 site, measuring the sound velocity across a block with a Pundit sclerometer and two opposite geophones.

After measuring the testing-probe (Fig. ESM01-5a), the geophones were applied in several scanlines, traversing the block from one side to the other. The measurements were somehow dependent on the orientation of the geophones in relation with the baseline direction, and on the contact geophone/block surface (enhanced with gel). In some scanlines, we measured the average travel time (Fig. ESM01-5b), computing later the average Sound Velocity (SV), whereas in other scanlines the measurement resulted in low or zero energy reaching the opposite geophone. This is because the wave propagation is sensitive to the internal structure of the block (existence/aperture/position of joints, cementation/fill). Finally, we assessed the overall block quality taking into account not only the SV's, but also the "arrival/non arrival" of the ultrasonic energy in the different scanlines. The parameter to quantify this overall quality is named "*i_pundit*" (Table 8 in the main text), and listed for each block in ESM_07.pdf.

a) b)

Figure ESM01-5. Pundit sclerometer. a: measuring the test-probe. b: the travel time allows calculation of Sound Velocity (SV).

Just before the test, rods, surveying staffs and targets were placed spread over the scene (Fig. ESM01-6). These items will be used as Ground Control Points (GCP) and/or as metrical scales in order to georeference all the photographic and video images, terrestrial and aerial (drone takes). The theoretical minimum number of GCP for the orientation of a 3D model is three; in addition, aerotriangulation can be used. Nevertheless, it is advisable spreading a higher number of points over the scene in order to have redundancy, and to cover unwanted occultation (dust, the block itself) and/or accidental destruction of targets due to the drops or to the evolution of the machinery. For these reasons, in each test we used between 10 and 20 targets and other auxiliary GCP (like crosses painted on rock outcrops, Fig. ESM01-2). We used a reflectorless Total Station and/or GPS/GNSS to position the GCP in a common reference system.

Figure ESM01-6. Detail of the targets and surveying staffs deployed over the scene for georeferencing.