DIGITISING SENSITIVE HERITAGE MONUMENTS IN ANTARCTICA

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ABSTRACT:

During the Antarctica expedition CHAQ2020, several cultural heritage sites – remains from the Swedish South Polar Expedition (1901-1903) – were documented using a range of different techniques and technologies. These physical monuments and environments are for all intents and purposes unavailable for most researchers due to their remote location and are also threatened by the effects of climate change. Hence, the deployed documentation techniques and technologies were selected both as a consequence of the inherently difficult conditions in Antarctica, where their reliance, durability, and speed were key considerations, but also for their perceived ability to document the unique and fragile environment. The documentation was carried out with the double intention of both allowing for observations *in situ* through processes of analytical drawings and data capture, but also capturing the environment as broadly and deeply as possible, in essence making a copy of it open for studies of unknown unknowns, that could serve as a source material for research questions still undefined. Hence, with the documentation of the winter station on Snow Hill Island as a case study, and with a perspective on documentation as a method through which to process, preserve, and disseminate information, this article serves to critically detail, compare, and evaluate the digital techniques and technologies that the expedition deployed to capture architectural elements and spatial contexts, and the data that could be obtained through these.

1. INTRODUCTION

Within heritage studies and archaeology, rich documentation of environments, especially when these are remote or inaccessible, is increasingly seen as an important research material as it both has the potential of reducing the need for travels and allow for new analytical methods, workflows, and perspectives. This is important from both an environment and quality perspective; not only do repeated trips have a costly environmental impact but experts whose skills are needed are excluded if the expedition is too demanding.

However, as places are made mobile through digital methods to serve as research material or even digital twins, this is a development which accentuates the need to transparently record and discuss both the process of data acquisition and what qualities of these places are preserved and archived (see van Lit 2020). As Derrida notes, archives are not created to serve the past, but instead the future (1995). Digitisation, therefore, as a concept, must be explored as a process that both transforms and limits future understandings of a place (Westin, 2021). Both the material and the immaterial aspects of a place constitute difficult problems in any effort of creating a faithful representation, and each step in the process requires intellectual and critical choices as digitisation is not a straightforward content-mining process; the persons, protocols, processes, and technologies involved are mediators that shape the result (see Dahlström, 2010; Björk, 2015:3). Furthermore, not least in the context of architectural digitization, of interest for a deeper understanding of what a digitization process produces is not only what characteristics of a place are selected for digitization based on available technologies and epistemological considerations, but also what limitations and conditions are present in the context of the digitization that further limits this selection.

To expand upon this line of reasoning this article critically details, compares, and evaluates the digital techniques and technologies that were deployed to capture architectural elements and spatial contexts on Snow Hill Island in Antarctica, and the data that could be obtained through these. The architectural remains from the Nordenskjöld expedition were investigated using both traditional and digital methods as part of the expedition CHAQ2020. The objectives for the fieldwork were to answer the need for a knowledge base for policy and decision making concerning the future of the remains of the Nordenskjöld expedition (1901-1903). Hence, the main undertakings for the fieldwork were to document the remnants, and to assess their condition to be able to propose recommendations. The documentation of the monuments and the immediate landscape involved manual scale drawings, drone-based and land-based photogrammetric triangulation, laser scanning, photography, and sound recording (Almevik, Avango, Contissa, Fontana, Lindström and Westin, 2021).

Figure 1. The Winter station on Snow Hill Island.
Photo: Jonathan Westin.

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2. THE REMAINS, THE EQUIPMENT, AND THE LOGISTICS OF THE DOCUMENTATION

2.1 The first expedition

In 1901 dr. Otto Nordenskjöld led the first Swedish South Polar expedition with a multidisciplinary team of researchers in geography, geology, medicine, and biology. The expedition set out to hibernate in Antarctica and stay for one year to survey the land, measure the climate, and collect samples. However, at the end of the first year the ship sank, and the expedition came to last more than two years until help arrived in November 1903 (Nordenskjöld 1904). When first arriving on the continent, the expedition members divided into groups to explore the Antarctic Peninsula. A prefabricated winter station of wood was brought from Sweden and erected on Snow Hill Island, serving as a base for Nordenskjöld and five other members of the expedition. When the ship Antarctic sank in February 1903 the groups got separated and two provisional stone huts were erected for shelter, one on Paulet Island and another on a peninsula named 'Hope Bay' by the expeditioners. The winter station, the remains of the two stone huts, and a cairn that was erected by the expeditioners on Seymour Island still exist and are protected as Historic Sites and Monuments (HSM) according to the Antarctic Treaty System (ATS) (Almevik, Avango, Contissa, Fontana, Lindström and Westin, 2021).

Figure 2. The original expedition members have just erected the winter station on Snow Hill Island. Photo: Gösta Bodman.

2.2 Equipment

The Nordenskjöld expedition's cartographer, Samuel Duse, notes towards the end of his autobiographical book *Bland Sälar och Pingviner* ["Among Seals and Penguins", our translation], that "if a Swedish polar expedition with solely scientific purposes would be carried out sometime in the future, I hope it will be conducted under more favorable conditions, with better funding, and first-class equipment, so it may result in even greater successes" (Duse 1905, p. 266, our translation). Though the original expedition handled advanced equipment for their time, CHAQ2020 brought documentation equipment that would appear magical to the original expedition.

In addition to a large number of cameras (including a Canon EOS 5D Mark IV, a Nikon D800, a Panasonic GF1, Fujifilm X-T2, two GoPros and a 360-camera), two small drones (a DJI Phantom 4 and a DJI Mavic 2 Pro with a 4K Hasselblad camera), five laptop computers and GPS devices, sun panels, and automatic sensors and loggers for precipitation, earth temperature, wind, and radiation, the expedition also brought a Faro Focus m70 laser scanner from the Gothenburg Research Infrastructure in Digital Humanities (University of Gothenburg) and an EinScan Pro 2X Plus structured-light scanner from the Heritage Visualization Lab (University of Gothenburg). Additionally, the expedition brought traditional measuring and drawing equipment, and all expedition members carried modern smartphones with cameras (Westin, 2020).

Hence, the documentation technologies brought to Snow Hill Island can be divided into six categories; (1) traditional drawing equipment (plumb lead and spirit level, chalk, pencils, graph paper, bearing compass etcetera), (2) camera equipped hand-held devices (cameras, smartphones), (3) drones (with cameras capable of taking still photographs and doing video recordings), (4) automatic sensors and loggers (for wind, humidity, temperature, precipitation, radiation), (5) 3D scanners, and (6) audio recorders. The type of documentation these technologies can capture can in turn be divided into six, slightly overlapping, categories; (1) traditional drawing documentation such as plans and sections, (2) 2D photographic documentation, (3) video documentation, (4) sensor-based documentation, (5) 3D documentation, and (6) audio documentation.

Through these technologies and those methodological approaches that they enabled, the expedition members were able to document several different aspects of the monuments. However, as this article argues, they also allowed the members to produce documentation at different speeds and abstraction levels, and adapt the precision of the documentation to logistics and conditions of the expedition.

2.3 Logistics

The equipment was brought from Sweden to Argentina with commercial air traffics, and with the help of Argentinian logistics first to Seymour Island with a Hercules plane and then to Snow Hill Island with Helicopter. The expedition had strict limits on total weight which impacted choice of equipment. For instance, it would have been advantageous to bring robust drones equipped with LIDAR and cameras that could capture multispectral imaging, but since that would necessitate leaving behind the terrestrial laser scanner and other heavy equipment deemed more important for the success of the expedition, the members opted for two lighter drones instead.

Figure 3. The harsh conditions for expedition. Photo: Jonathan Westin.

On site there were primarily seven conditions that had to be adapted for, which also affected the documentation strategies both in planning and execution: (1) intermittent access to electricity, (2) low temperatures, (3) hard winds, (4) mud and snow, (5) no access to technical support, (6) uncertain time frame for documentation, (7) lack of base documentation.

2.3.1 Intermittent access to electricity

The expedition brought a diesel-powered generator, but it worked only intermittently. This meant that the members had to plan for getting as much of the essential documentation done using the fully loaded batteries that were brought, and then, if batteries could be recharged, follow an expanded prioritization list.

2.3.2 Low temperatures

Since the expedition took place during the Antarctic summer, the temperature was expected to be around minus 10° C. However, as the wind came in over the glaciers it could be as cold as minus 28° C. This could potentially have a negative effect on the batteries' ability to keep a charge which meant the members had to be even more conservative when planning for how much documentation they would be able to do.

2.3.3 Hard winds

Winds regularly reach 100 km per hour, and even though such speeds were not a constant, the wind was always strong. This affected the possibility to fly drones, and even outdoor terrestrial laser scanning at most times during the day.

2.3.4 Mud and snow

The tents that were brought made it hard to keep working spaces clean and mud free. This made any operation involving more expensive or sensitive equipment – such as regular maintenance or offloading data – time consuming and perilous, as grains of sand or moisture could break them.

2.3.5 No access to technical support

As there were no internet access, and no cell phone reception, if a certain license, software, or hardware would fail or need to "call home" to be operational, there would be no way of solving it. This meant that only solutions that worked off-line could be used, and any mission-critical software had to be installed on at least two different machines.

2.3.6 Uncertain time frame for documentation

Due to quickly changing weather conditions any transportation between sites had to happen when there were favorable conditions. Hence, there was no way of knowing how much time for documentation was available at each site, which imposed a double importance of strictly following a prioritization list.

2.3.7 Lack of base documentation

As the expedition members had no access to any documentation of the Snow Hill Island site, only a few historical photographs, it was a challenge to discuss and conceptualize the place in preparation, to establish relevant prioritization lists, and to plan actions.

3. THE DOCUMENTATION

3.1 Adapting to conditions

The extent and limitations of the data the expedition was able to bring back from Antarctica, all stemmed in some ways from adapting to, or resigning oneself to, the conditions listed above. Due to condition 1 and 4, where the members were both constrained by the need to conserve battery power and did not have access to clean environments, there was no reliable way to use digital methods and technologies – such as drone photography or laser scanning – to produce an overview map that could be used when planning actions. Processing and consulting such work material would consume battery cycles better used for the main documentation effort. This also meant that a majority of the work had to be done without the possibility to neither inspect the result and make corrections nor collect additional data, thus consciously ignoring an important step of quality control and on-site evaluation.

Moreover, since there was uncertainty about how the digital storage devices would fare being exposed to cold and moist environments for up to a month, the expedition decided early on to also deploy traditional drawing techniques. This would (a) provide the members with documentation of the site that could be used in planning activities and interventions, (b) allow for an on-site analysis of the winter station and environment while doing the documentation, and (c) produce non-digital documentation that would not be subject to the same risks as hard drives.

To critically discuss the impact of the conditions on the use of various methods and technologies, below follows both a description of the methods used to acquire 3D data of the Snow Hill Island site, and the non-digital methods deployed as a safeguard and on-site analytical method.

3.2 3D documentation

To be confident in being able to leave Snow Hill Island with adequate 3D data, it was decided that the interior and the exterior of the Snow Hill winter station were to be captured using two different techniques and technologies; Structure-from-Motion (henceforth referred to as *photo scanning*), and laser scanning. In addition to this, a structured-light scanner was also used, but only for a limited number of isolated artefacts as it is not suitable for digitizing spatial contexts.

3.2.1 Obtaining 3D data through photo scanning

Any of the 24 camera-equipped devices the members were bringing on the expedition (ranging from web cameras to DSLRs) could be used to capture data for ground-based photo scanning, though with dramatically different levels of quality. Hence, not being dependent on a single device (see condition 1 through 6) it was reasoned that photo scanning was a reliable technique. Depending on the object, different procedures are followed when taking the photos. Though it takes training to master and get consistently reliable results and be able to adapt to different conditions, the basic process of data collection is relatively simple to offer instructions for. Hence, for acquiring at least basic 3D data it was a technique also not reliant on a single expedition member. The exteriors of the winter station and immediate surroundings were documented with approximately 7000 images, as this was deemed enough to produce a model that would represent all structural features as geometries, while finer details would instead be communicated through the color information of the texture.

To complement the photo scanning performed with the DSLRs, the two drones were used to capture a large stretch (approximately 400 by 2000 meters) of the landscape in 3D. This was done through two different techniques over the course of multiple flights, and the photos from these flights were combined into one model. The first technique involved setting the drone on a preprogrammed path taking photos straight down at 70 percent overlap. These flights were done on several different altitudes, ranging from three meters above ground level close to the main site, to 400 meters above sea level further away and over the mountains and glaciers. The second technique involved manually flying the drone in concentric circles around the winter station and the various hills where field stations had been erected by the original expedition with the camera at a 45-degree angle towards the center of the circle. This was done while recording video with the 4k Hasselblad camera of the DJI Mavic 2 Pro. Due to hard winds (see condition 3), most drone documentation had to be done early in the morning or late in the evening when the wind was less strong. However, this also meant less than optimal light conditions which reflects on the result.

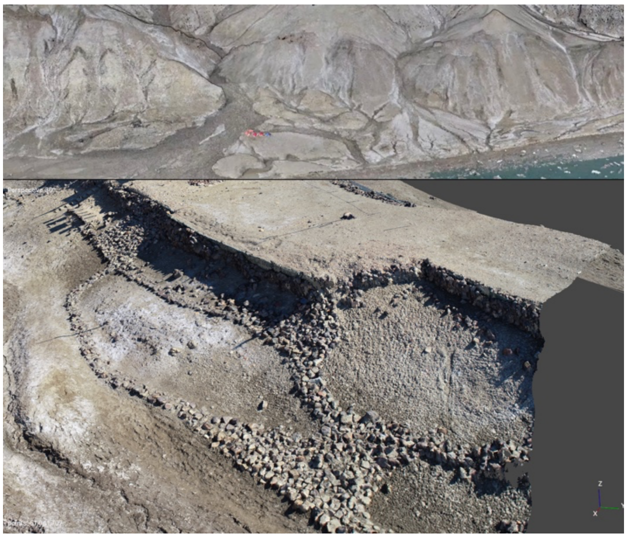

Figure 4. The computed landscape from a far, and a close-up of the hill the winter station stands on.

The documentation of the interiors through photo scanning was hampered by several factors, primarily logistics and condition 1 and 6; lack of light, lack of power, and uncertain time frames. The expedition did not have the possibility to bring bright LED panels, and even if storage and weight had not been a problem, the energy these would have consumed would have proven a challenge. Without proper light, the harsh contrast between the light coming in through the windows and the otherwise dark interiors – a darkness accentuated by the grey cloth the outer walls were isolated with – had to be mitigated by high density range photography or long exposure times. However, this demands the camera to be operated on a tripod which would have complicated the documentation of a furnished environment and added days to a photo scanning that was estimated to require up towards ten thousand photos. Hence, any proper effort to document the interiors through this technique conflicts with other expedition members' need to access the winter station for their work (see condition 6 - uncertain time frame).

3.2.2 Obtaining data through laser scanner

The laser scanner that the expedition brought, a Faro Focus m70, is primarily used for scanning environments, both natural and built, rather than artefacts. Mounted on a tripod it rotates slowly while registering up towards a million points a second. However, as it can only register measure points on surfaces that it can reflect laser points to from its fixed position in space, a furnished room often requires four or more separate scanning positions to be accurately covered. To also capture the topside of high shelves and details underneath chairs and tables, even more positions might be needed at various heights. Consequently, to capture a furnished space requires planning, and for the exterior scanning the weather conditions also affect the available options (Westin, 2020). For instance, a hard wind, rain, or snow (see condition 3 and 4) severally limits the use of the laser scanner.

Figure 5. Laser scanning the interiors. Photo: Gunnar Almevik.

To plan for the laser scanning, before the start of the expedition a simple 3D model of the interiors was created by consulting historical photos and drawings. From that model positions where then calculated indicating where the scanner would have to be placed to capture as much of the interiors as possible in as few scans as possible. The efficiency of this work was crucial since each scan consumes between 6 and 8 percent of a battery on the preferred settings (see condition 1 and 2). As a scan averages 17 minutes at these settings, there was also the time aspect to consider: an inefficient scanning procedure, where a greater number of positions were needed, would make the winter station inaccessible for the other researchers for days. If the expedition was cut shorter than expected (see condition 6), this would in turn lead to no data acquisition except the laser data. With these considerations in mind the expedition came up with 28 prioritized scanning positions for the interiors of the station, which would amount to nearly twenty billion measuring points of raw data, and could be finished in a day and within the budget of the two fully charged batteries that were brought (Westin, 2020).

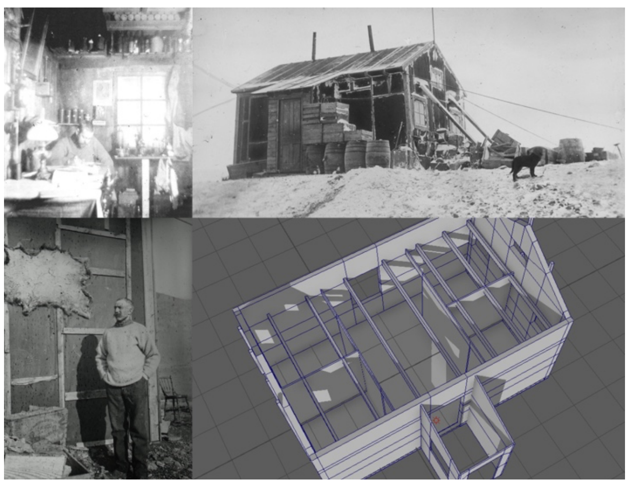

Figure 6. Historical photos and a simple model to plan for efficient scanner positions.

However, as a result of prioritizing the recharging of the scanner's batteries when the electricity generator was working, it was

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possible to scan parts of the exteriors, at four different occasions at different settings. This resulted in approximately 70 scans that also captured the surrounding landscape within a 100-meter radius of the winter station at a resolution of up to one measuring point per 1.5 millimeters.

3.2.3 Obtaining data through structured light scanning

The structured light scanner that was brought, an EinScan Pro 2X Plus, demanded constant power supply as it did not have any battery. Furthermore, to be operated it had to be connected to a laptop computer with a high-end graphics card that consumed a substantial amount of energy, which in and by itself, even if the scanner had been battery-powered, would have limited any scanning session to about 30 minutes before the laptop battery would have drained (see condition 1 and 2). This meant that structured light scanning was limited to those occasions when the power generator was operational, which in turn led to conflicts with other expedition members' need to access the winter station for their work (see condition 6 - uncertain time frame) if they needed access to the same artefacts (conservation and documentation efforts) or the entire winter station (laser scanning of the interiors).

3.3 Obtaining data through manual drawing techniques

For the traditional drawing documentation, which included both a map of the area and the winter station itself, the expedition made use of a clinometer for measuring the angle of inclination, a measure tape for the distances, and a bearing compass adjusted for use in the South Pole with a calibration for the magnetism that otherwise bends the arrow downwards. The method was comparable to the one used by the Nordenskjöld expedition where first a polygon was established around the area from which details are triangulated or aimed. The polygon had twenty-one points, and when the last angle and distance was measured, the connection of the first and last failed by three meters. Considering the large area, 24000 square meters, and a manual technique, it was considered accurate enough, and the errors were distributed some decimeters on each point (Almevik, 2020).

As the map was finished on site and resulted in a tangible format, the expedition was able to activate it as a tool for collecting data. Following an object and location number series that was established on the map, expedition members organised a walking interview with those officials from *Instituto Antártico Argentino* that were part of the expedition. Being in a physical context evokes memories and narratives that do not emerge in an interview removed from the physical place. The environment and various objects become actors in the narrative. Hence, the walking interview, both recorded through and directed by a graphical representation, becomes a method to elicit information from these "mnemonic actants" (Almevik, 2020).

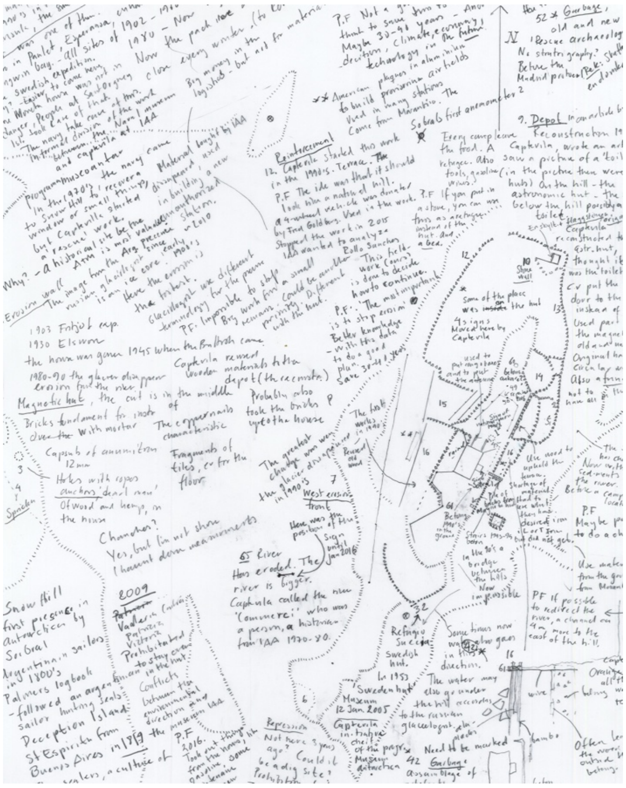

Figure 7. Detail of walking map with notes.

The winter station was measured in scale 1:20 from a system of horizontal and vertical reference lines. Following through on the ambition of only utilizing traditional tools and techniques for the manual drawing, only traditional plumb lead and spirit level were used. With a chalk liner reference points were marked, and from this fixed system the irregularities of the building were revealed and accounted for. In addition to facades, planes and sections, the set of drawings produced through the manual drawing techniques included details of doors and windows, all in scale 1:5 and 1:2.

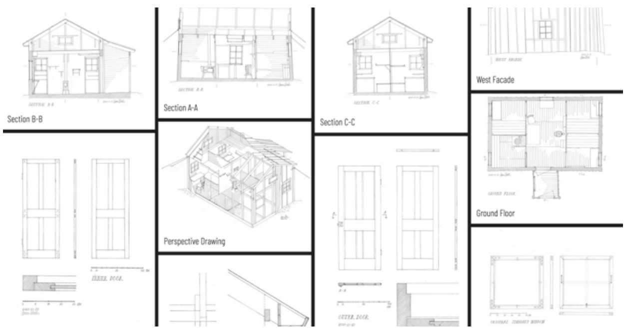

Figure 8. Collage showing manual documentation.

4. AN EVALUATION OF THE DEPLOYED METHODS

As has been shown, for a comparison and evaluation of the techniques and technologies that the expedition deployed to capture architectural elements and spatial contexts, it is not enough to evaluate the data that could be obtained through these, but also the conditions that had to be adapted for and how they locked into or disrupted other on-site work. While the conditions of Antarctica are in many ways extreme, any data collection is hampered to some extent by conditions that demand adaptations on-site.

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In contrast to laser scanning, photo scanning could still be performed in rain or hard wind if the lens is kept free from water drops and dust. Depending on the rain, a small lens, like that on a cell phone camera, was preferred since it is a smaller target for water drops that could risk warping the result and create issues with focus (Westin, 2020). Thus, adapting by switching to an inferior camera system was considered advisable when the optimal solution was rendered uncertain by the conditions, but such changes also require changes in methods and data collection practices, and it requires skill to know how and when to adapt. However, when snowing, outdoor photo scanning was not possible at all, as snowflakes introduces noise into the image processing and appear in the texture information.

While photo scanning of exteriors and artefacts are relatively straightforward, the advantage of the laser scanner in more complicated environments, such as furnished interiors, is that the measuring points provide more reliable data, while a photo scanning process could result in highly erroneous data due to dark or noisy photographs, an inadequate number of images, repeating patterns that confuses the identification of necessary key points, or an unstructured way of taking the photos (Westin, 2020). While the general layout of an unfurnished room could be computed from less than a hundred photos, the necessary number exponentially grows for each additional object in the room as these also must be photographed from an adequate number of angles. Likewise, if geometrical data about cutmarks, inscriptions or textures are to be captured, then a square meter of wall could demand a thousand photos by itself and additional lights to keep ISO level low and the focus sharp.

Just as the strong wind (see condition 3) prevented any outdoor laser scanning except early in the morning or late in the evening when the wind died down, Antarctica offered some further unique conditions not foreseen; the eroding moraine shifted under the tripod from the vibrations caused by the rotational movements of the laser scanner. When capturing the photographs for the color information, this made the tripod slightly shift position between each photo, which in turn led to a blurry appearance in the colorized point cloud. This did not affect the laser data as the measure points are captured faster than the color data, and the slower and smoother rotational movement of the scanner during that phase did not have the same impact on the moraine. The problems with capturing color data were in some ways mitigated by the construction of a platform for the tripod that prevented it from sinking, and the addition of hanging weights to make the tripod more stable in the wind.

Figure 9. Laser scan of exteriors without color.

While strong wind, sharp light, rain, and snow affected both the photo- and laser-based scanning methods, the traditional measuring equipment and methods were unaffected. However, one may question the value and efficiency of traditional measuring methods; when the laser scanner collects a million measure points per second, traditional methods require several days to collect a thousand. Furthermore, the tip of the pencil compromises the accuracy of several centimeters in the two-dimensional scale drawing when the laser represents the whole complex environment in dynamic 3D models with a resolution of 1 point per millimeter (Almevik, 2020). However, as has been argued, various techniques, whether traditional or through scanners, do not substitute one and another but represent unique ways of knowing and recording, and the affordances of each method must be independently assessed (see Morgan and Wright, 2018; Morgan et al., 2021).

One problem with advanced digital technologies in this field-based situation, with no internet access (condition 5) and limited data power and electric supply (condition 1), is that there are few opportunities to gauge the quality of the data. By contrast, drawing is not just a way to put to paper a graphical representation – to create a material inscription of what is observed – but also a method for a systematic observation and evaluation of the acquired data on-site. The practice of drawing evokes a mode of attentive and reflective seeing; it leads the researcher into every angle of the winter station and the process demands a conscious reflection of what to represent and what to suppress. Hence, the process of manual data collection and data analysis is integrated as the analysis of the information is made *in situ,* while data collection through laser or photo scanning constitutes a delaying of analysis; an archive process where the collected data lies in waiting of an analysis.

However, approached as such an archive process to serve the future rather than a process of observation and analysis *in situ*, the data collection – if it is broad, diverse, and deep enough – has the possibility of also capturing the *unknown unknowns:* the information layers whose outlines are yet to be traced and therefore unconsciously ignored by the selective nature of traditional documentation methods. When approached as a process of data collection and archiving rather than an investigation, each step of the process becomes important to consider as future research is limited by the depth of the data. The analytical work is still pushed to the future, but the data constitutes a possible source for discoveries long after the winter station is gone.

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The born digital and digitised data from the fieldwork is open and accessible through a project repository provided by the University of Gothenburg's Research Infrastructure in Digital Humanities (GRIDH) and the Department of Conservation (accessible at https://antarctica.dh.gu.se).

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