



SVALBARD ENVIRONMENTAL  
PROTECTION FUND



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and Benjamin Koster*

# **Interdisciplinary archaeological fieldwork on Blomstrand, Kongsfjorden, Spitsbergen**

**Final report**

**July 12 – 20, 2014**



## **Non-technical summary**

In July 2014, researchers carried out interdisciplinary fieldwork at the former British mining settlement and quarries on Blomstrand in Kongsfjorden, Spitsbergen. They formulated two main questions: **1) why did past attempts to quarry marble on this Arctic island fail and 2) what was the lasting impact of this industry on the local environment?** In order to generate answers, the archaeologist enlisted the help of a geologist, a biologist, and a team of divers. The geologist carried out a ground-penetrating-radar (GPR) survey to investigate the quality of the marble below the surface. The biologist conducted a vegetation survey to identify any foreign plants that the miners might have introduced and to look for signs that livestock known from old photographs might have fertilised the ground. The divers inspected the small natural harbour of Peirsonhamna to see if the industrial past had left any submerged traces. In addition to the fieldwork, the archaeologist undertook archival research in Great Britain in autumn 2014 to search for other real or potential reasons that could have caused the abandonment of the quarries.

The geologist was able to show that the marble was frequently fractured, but between fracture zones, there were also areas of rock that could have been worked successfully. The biologist identified newly appeared plants, especially grasses, which grew around some but not all of the former buildings in the settlement. Further analysis will have to show whether the animal (or human) dung had enriched the soil. The diving team found only a few large metal objects under water, which provided common algae with fixed hard surfaces on which to grow, but on the whole, the mining operations did not seem to have had any visible effect on Peirsonhamna.

While the GPR survey was inconclusive about the reasons for the site's abandonment, the historical documents consulted in British archives suggest some serious foul play by the company before and probably after the First World War. They also show that there was a growing demand for marble before the conflict. Afterwards, the market crashed because the British Government subsidised affordable housing for returning British soldiers instead of wasting limited resources on luxury building, i.e. the construction of villas, cinemas, theatres, and such like. It appears that the discontinuation of the marble quarries had little to do with the actual stone but was a logical decision in view of what was happening in Europe at the time.

## **Keywords**

Archaeology, Blomstrand, development, diving, environmental impact, geology, GPR, historical ecology, history, industry, marble, metal detecting, mining, newly appearing plants, quarrying, Spitsbergen, Svalbard, vegetation

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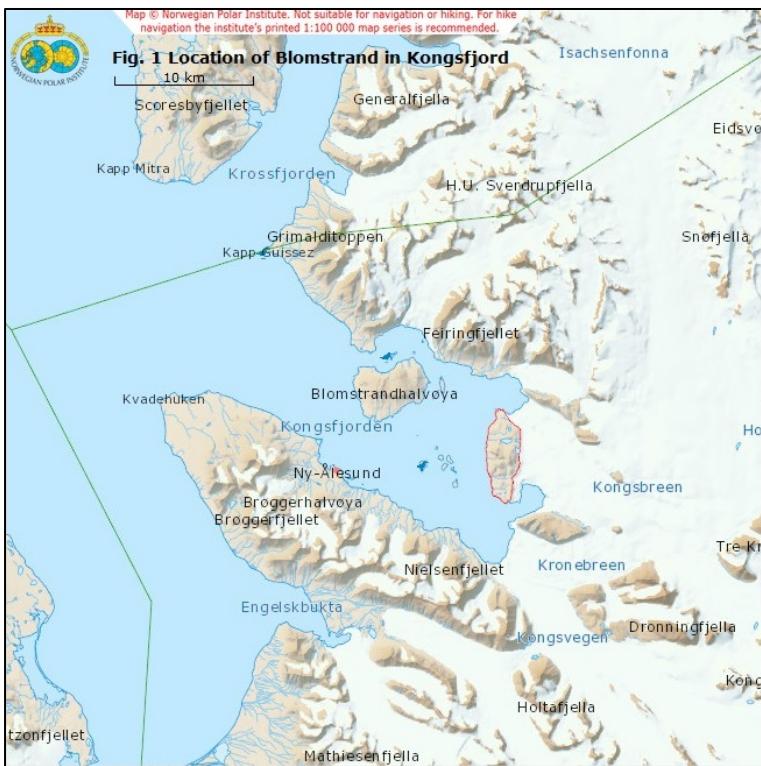
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## Introduction

Interdisciplinary archaeological fieldwork took place on the Arctic island of Blomstrand in Kongsfjorden, Svalbard, Norway, approximately 78°57'41"N and 12°2'38"E (Fig. 1) between July 12 and 20, 2014.



**Fig. 1** Location of the Arctic island of Blomstrand in Kongsfjorden, Svalbard, Norway. (Map: Norwegian Polar Institute)

It comprised a non-intrusive ground-penetrating radar (GPR) survey, a vegetation survey, and a reconnaissance dive in Peirson-hamna. These investigations were undertaken as part of two different research projects. The first was “Marble at Fault” (RiS ID 6912), which was funded by the Svalbard Environmental Protection Fund

(Svalbards Miljøvernfon) and supported by the University of Groningen (RUG). The second was "Environmental consequences of four hundred years of natural-resource exploitation on Spitsbergen" ("Consequences of exploitation" in short, RiS ID 6917), which was funded by the Netherlands Organisation of Scientific Research (NWO) and also supported by the RUG. Throughout the fieldwork and on both projects, the archaeologist and author of this report Dr Frigga Kruse of the Arctic Centre of the RUG was the principal investigator. She is indebted to the geologist Dr Benjamin Koster of RWTH Aachen University, the biologist Dr Maarten Loonen of the Arctic Centre of the RUG as well as station leader of the Netherlands Arctic Station in Ny Ålesund, and the diving supervisor Mr Max Schwanitz and his team of divers of the Alfred-Wegener-Institut (AWI) for their invaluable scientific expertise and practical support in the field. The fieldwork also benefitted from the extensive logistical services offered by Kings Bay AS in Ny Ålesund. Furthermore, Kruse extends her thanks to the Georadar-Forum for critical methodological recommendations as well as the Svalbard Museum and *Svalbardposten* for providing an important platform for education and outreach.

## **Aims and objectives**

The fieldwork being part of two different research projects, it combined the aims and objectives of both in equal measures.

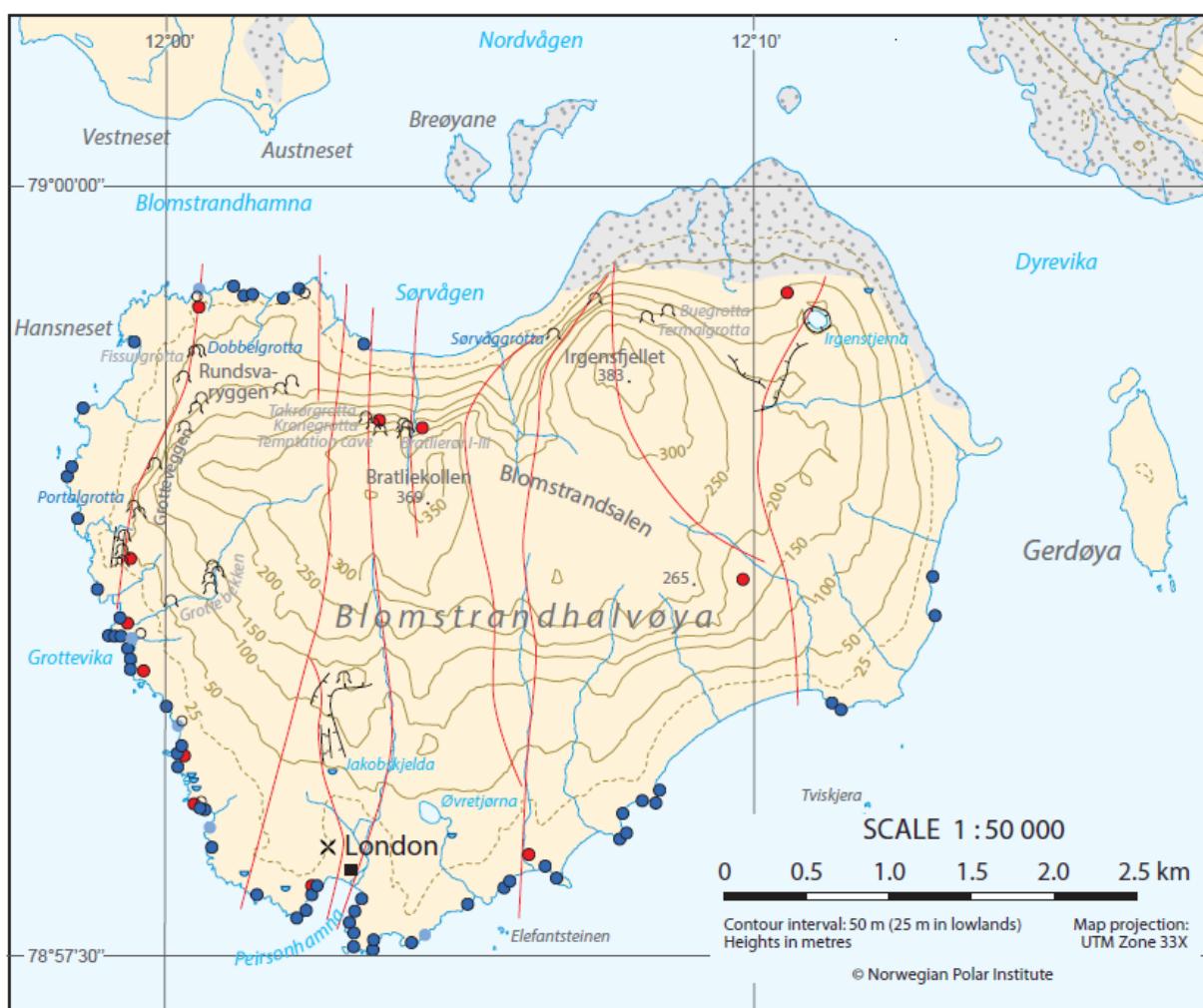
The overall aim of “Marble at Fault” was of an industrial archaeological nature. The project aimed to disclose why historical attempts of large-scale quarrying of High Arctic marble failed on Marble Island (historically speaking). During the fieldwork, Kruse intended to test the hypothesis that structural geological changes had negatively affected the marble (Siggerud 1960) by engaging geological expertise to conduct a non-intrusive geophysical survey at carefully chosen locations on the island. More specifically, ground-penetrating radar (GPR) would be used to discern if there were structural weaknesses in the vicinity of known historical quarries and boreholes, which may be to blame for their abandonment. The title of the project “Marble at Fault” is a play on words as a certain type of structural weakness is known in geology as a fault. To prevent foregone conclusions, Kruse also carried out additional archival research in Great Britain after the fieldwork with the objective of identifying other reasons, real or potential, for the discontinuation of the quarries.

The overall aim of “Consequences of exploitation” was rooted in historical ecology. The project aimed to qualify and quantify the anthropogenic impact of historical exploration and quarrying on the local terrestrial and coastal ecosystems of Marble Island. Hence, Loonen undertook a vegetation survey in order to identify non-indigenous plant species, specifically grasses, that may have been introduced as a result of the industrial operations. Secondly, Schwanitz and a team of divers carried out a series of dives in the natural harbour of Peirsonhamna in order to detect if the operations had any lasting effects under water.

Broadly speaking, the fieldwork would generate new knowledge about Svalbard’s industrial past and cultural heritage, thereby improving academic and public awareness of this historical mining site. Uncovering crucial information about the hitherto poorly understood and probably unique material remains of Arctic marble quarrying could potentially benefit the archipelago by enhancing their value as a source of historical and polar knowledge, as an intense visitor experience of a bygone industrial age, and as a source of revenue through improved tourism.

## Geological, tectonic, and historical-archaeological setting

The focus of the interdisciplinary fieldwork lay on the south-western quarter of Blomstrand between Peirsonhamna on the south coast and Grottevika on the west coast (Fig. 2). As the historical British name of Marble Island suggests, an Englishman found it to consist of marble in 1906, and a range of material remains attesting to subsequent exploration and quarrying are well-preserved here. It is important, therefore, to gain an understanding of the underlying geology of those areas that merited further investigation as well as the historical-archaeological work done to date, in particular any questions left unanswered.



**Blomstrandhalvøya, karst features**

Bedrock with no or thin cover	Moraine cover
X Marble quarry, abandoned	● Palaeokarst (Devonian and Carboniferous)
■ Mining site, abandoned	— Fault in bedrock
	● Marine cave, active
	● Marine cave, relict
	○ Karst cave, relict
	— Escarpment of karst origin
	— Spring
	○ Doline, sinkhole

**Fig. 2** The island of Blomstrand. The fieldwork focussed on the south-western quarter between Peirsonhamna to the south and Grottevika to the west. (Map: W. Dallmann.)

### ***Geological and tectonic setting***

Svalbard represents the emergent northwestern part of the Barents Shelf, which uplifted during the Late Mesozoic and Cenozoic (e.g. Johnson et al. 2001, Dallmann 2007). The uplift of the archipelago was most extensive in the northern and western parts, leaving gradually older rocks in those directions (Johnson et al. 2001). The geological record of Svalbard ranges from possible Archaean age to the recent past and shows a multi-orogenic development with prominent tectonic events at several ages (e.g. Dallmann 2007, Elvevold et al. 2007). The main geological record of Svalbard can be separated into three broad divisions: the basement of igneous and metamorphic rocks formed during Precambrian to Silurian times, which has suffered several episodes of folding and alteration; unaltered Late Palaeozoic to Cenozoic sedimentary rocks, which form a trough-shaped structure (Central Tertiary Spitsbergen Basin) from the Isfjorden area (central Spitsbergen) to the south; and unconsolidated Quaternary surficial deposits formed during and after the last ice age (e.g. Dallmann 2007, Elvevold et al. 2007).

A dominant NNW-SSE trending structural grain on Spitsbergen comprises several similarly aligned episodes of tectonic deformation (e.g. Johnson et al. 2001, Pirli et al. 2013). Svalbard's tectonic and geologic regions may be divided into: Precambrian to early Silurian rocks (Pre-Old Red basement) in the north-eastern part of Spitsbergen and on Nordaustlandet; Devonian cover rocks and grabens on northern Spitsbergen; the Central Tertiary Spitsbergen Basin; Triassic and partly Cretaceous platform areas on the eastern parts of Spitsbergen and on Barentsøya and Edgeøya; and the Tertiary fold-and-thrust belt along the west coast of Spitsbergen, which has possibly reactivated older structures (e.g. Johnson et al. 2001, Dallmann 2007, Elvevold et al. 2007).

The area under investigation in this study is located in the Kongsfjorden area (northwestern Spitsbergen), which is characterised by Mesoproterozoic rocks in the northern part, respectively Carboniferous and Permian as well as Palaeogene and Neogene rocks in the southern parts of the fjord. The NNW-SSE trending faults by the Tertiary fold-and-thrust belt dominate the younger tectonic regime in this area. Furthermore, deglaciation of the Kongfjord is reported since the Late Weichselian (e.g. Lehman & Forman 1992, Lauritzen 2006, Ingólfsson and Landvik 2013) and is linked to sea level changes and following tectonic uplift that still affects the study area.

Blomstrandøya (Marble Island) consists mainly of medium to high-grade metamorphic Caledonian marbles as well as pelitic schists and gneisses (e.g. Thiedig and Manby 1992, Lauritzen 2006). Thiedig and Manby (1992) as well as Lauritzen (2006) describe the Caledonian rocks striking N-S and having been affected by two synmetamorphic, co-linear phases of isoclinal folding as well as refolding by post-metamorphic crenulation to kink-folds, which are often associated with west-directed thrust faulting and imbrication.

Additionally, some small patches of unmetamorphosed, possibly Devonian, sediments are widely scattered on Marble Island (Lauritzen 2006). These sediments are either preserved in wedges associated with faulting and brecciation of the underlying marbles, or they occur in fan-shaped bodies filling channels and tubes in the marbles. Furthermore, these sediments are often injected into a mesh of calcitic veins which penetrate parts of the marbles (Thiedig and Manby 1992, Lauritzen 2006). The uplifted coastline of Marble Island is also characterised by some karstic caves which formed during the last thousands of years (Lauritzen 2006, Fig. 2).

In present geological or tectonic maps (e.g. Buggisch et al. 1992, Thiedig and Manby 1992), thrust faults or folds are not indicated within the areas of the GPR survey grids. However, we have observed several secondary features (e.g. cracks, fracture zones, or a natural slip surface) which are most likely related to fault or isostatic uplift activity (Fig. 3).



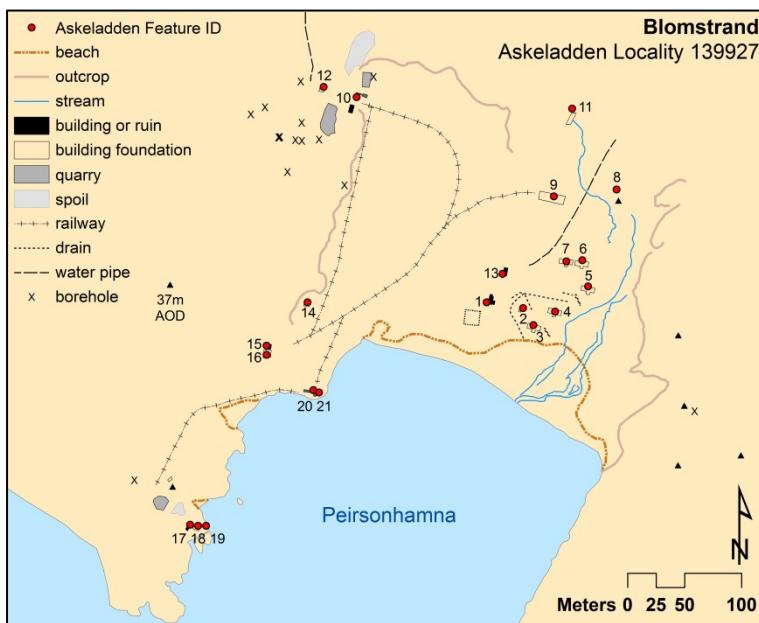
**Fig. 3** A recent crack probably caused by tectonic uplift that still affects Blomstrand, looking south towards Ny Ålesund. (Photo: F. Kruse.)

A question which geologists often do not stop to ask, probably because of the chasm between geological and archaeological/historical scales, but which is

crucial to this study is how much geological knowledge was available to the historical actors arriving on Blomstrand a century ago. In fact, the chemistry of marble and its geological formation did not need to be a mystery (unless one did not care to inform himself properly). In 1909, William George Renwick published 'Marble and marble working' which treated the dimension stone on a global scale. Unfortunately, the author of this report only became aware of the readily available e-book at the time of writing, so that much of its valuable information could not be included in the text. Suffice to say that a general knowledge of marble existed but that local knowledge of the resource on Blomstrand and how to work it needed to be generated on site.

### *Historical-archaeological setting*

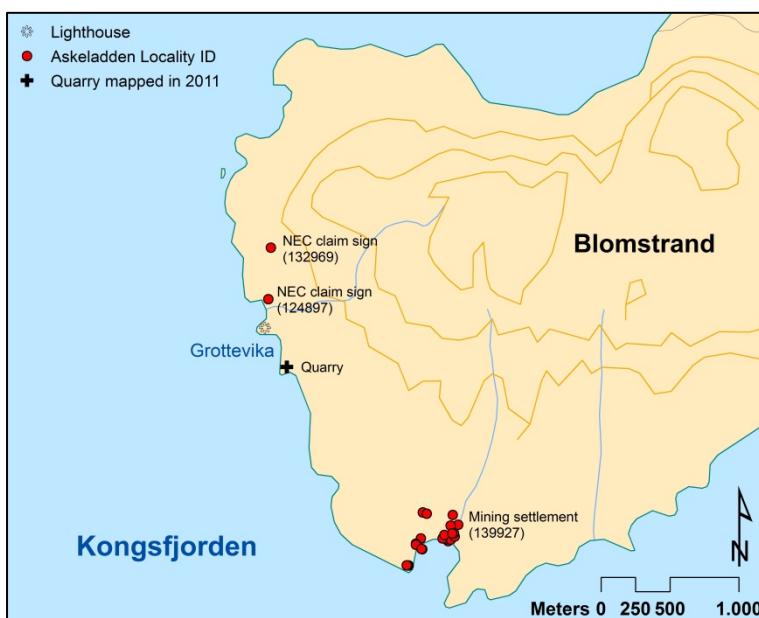
The English prospector Ernest Mansfield, having had some prior experience of marble quarrying, discovered Marble Island in summer 1906. Development did not start until spring 1911 and, after a voluntary absence during the First World War, only lasted until 1920.



**Fig. 4** The mining settlement and quarries at Peirsonhamna, anachronically known as Ny London. The map indicates the overlap between features listed in the Askeladden database (numbered) and additional features mapped during the LASHIPA Project in 2008. (Map: F. Kruse.)

The material remains of Blomstrand are now protected,

and many but not all are recognised and listed in the Askeladden database ([askeladden.ra.no](http://askeladden.ra.no)). In 2008, the LASHIPA Project (“Large-scale historical exploitation of polar areas”, RiS ID 3106) carried out an industrial archaeological survey of the mining settlement and quarries at Peirsonhamna (commonly but anachronically known as Ny London). The survey results have been reported in Aalders *et al.* (2009). The overlap of Askeladden and LASHIPA is indicated in Fig. 4.



**Fig. 5** In 2011, Dutch researchers reported a small quarry to the south of Grottevika. (Map: F. Kruse.)

Moreover, researchers of the Netherlands Arctic Station surveyed a small historical marble quarry to the south of Grottevika in 2011. Besides an extensive mention on the Station’s weblog

(poolstation.nl), this quarry remained unreported. It currently does not have a corresponding Askeladden entry, while two claim signs of the Northern Exploration Company (commonly abbreviated to NEC) to the north of Grottevika do (Fig. 5).

Within the LASHIPA framework, Kruse (2013) investigated the activities of the Northern Exploration Co. She has been able to conclude that the history of the High Arctic marble quarries remains poorly understood and is probably unique in the polar world. Yet, the documents she has consulted to date are vague about the workability and the profitability of the natural resource. Unknown sources have been quick to pinpoint the effect of permafrost, which supposedly thawed upon transportation to warmer climates, to be the main reason behind the company's failure to exploit the dimension stone. This has been repeated uncritically in several current guide books (e.g. Hermansen 2007, 162; Umbreit 2009, 137; Johannsen 2011, 155) and has unfortunately found its way onto the internet and into many tourists' blogs. Thankfully, Stange simply refers to the quality of the marble being low due to 'many cracks' (2011, 301). Since in geology, cracks can have different origins, this statement allows room for analysis and reinterpretation. In fact, the notion of permafrost being to blame has already been investigated and discarded by Siggerud (1960). He instead proposes potentially unfavourable structural geology such as subsurface fault patterns, which would cause the marble to fail on a medium to large scale. His hypothesis had not yet been tested.

On the note of environmental consequences, it is assumed that the historical actors did not care too much about these unless their direct causes also hindered the operations and affected profitability. It is highly doubtful that any of the actors were aware of creating what is today an archaeological site, let alone having lasting and measurable effects on local ecosystems.

## **Methodology**

### *Practical limitations to the fieldwork*

Owing to Blomstrand's relative isolation, there were limitations to the fieldwork that could be carried out within the financial and time constraints. Most conveniently, researchers fly from the Norwegian mainland via Svalbard's capital of Longyearbyen to the scientific village of Ny Ålesund ( $78^{\circ}55'30''\text{N}$   $11^{\circ}55'20''\text{E}$ ). They commonly ship any heavy or bulky equipment well in advance of the field season. The GPR equipment could not be shipped because it could not be spared by the Georadar-Forum until close to Kruse's and Koster's actual date of departure. Hence, Koster was forced to reduce the weight and size of the equipment, including his personal belongings, to approximately 40kg. This still exceeded the very strict allowance of 20kg per person on flights between Longyearbyen and Ny Ålesund, but timely registration with Kings Bay AS and paying for the excess luggage took care of this. The informal suggestion of taking a chance with more equipment since occasionally flights are not fully booked was immediately disregarded. Having a very narrow fieldwork window of only seven days, we could not risk any of our equipment not reaching Ny Ålesund and in turn Blomstrand. As a result, Koster worked with only one antenna instead of the usual range of three antennae. Kruse had prepared to take a Differential Global Positioning System (dGPS) to Blomstrand. She was aware that Ny Ålesund is a 'radio silent area', a fact that is drummed into any visitor in the possession of a mobile phone. However, in the absence of easily accessible details about this radio silence or a map of its extent, she did not realise that the area extended across Kongsfjorden to Blomstrand. She was hence not permitted to use the dGPS and needed to borrow an unfamiliar instrument. Unfortunately, this instrument, while clearly indicating altitude on the screen, failed to record the important data, which undermined the results and success of the fieldwork.

### *Ground-penetrating radar(GPR) survey at the quarries, conducted by B. Koster*

In 2008, members of the LASHIPA Project observed a substantial fracture zone in the historical Winter Quarry (1919/20) on Blomstrand (Fig. 6). They were also able to trace several cracks on nearby outcrop surfaces. Although this fault may have been an obvious reason behind this particular quarry's abandonment, it was outside the scope of their fieldwork to examine this assumption further.

Between July 12 and 16, 2014, a ground penetrating radar (GPR) survey was therefore carried out to investigate these and other possible zones of weakness such as cracks, faults, and holes in the subsurface. A medium-frequency antenna promised to be the best compromise between the spatial resolution of any cracks or faults, and the achievable penetration depth. As can be seen in Appendix 1, A1.1, we used a GSSI 400MHz antenna with a survey wheel, a SIR-3000 data acquisition system,

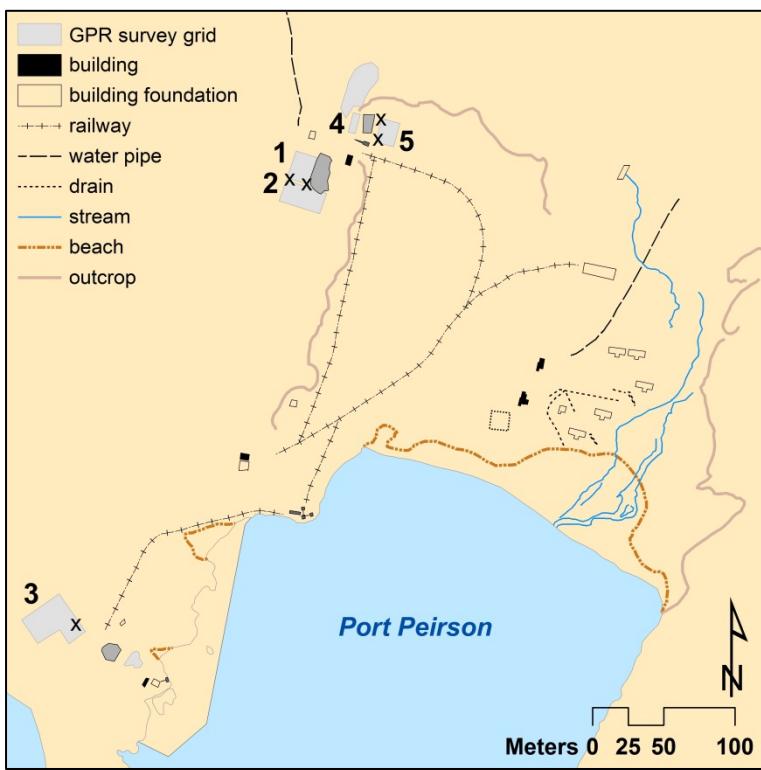
and a handheld GPS. Trace increment was set to 0.02m in order to achieve a high data density; the range was set to 90ns TWT with a sample rate of 1024. Using the 400MHz GPR antenna, a GPR target depth of approximately 4m could be aimed for.



**Fig. 6** A fault and a natural slip surface observed in a historical quarry on Blomstrand in 2008.  
(Photo: D. Avango.)

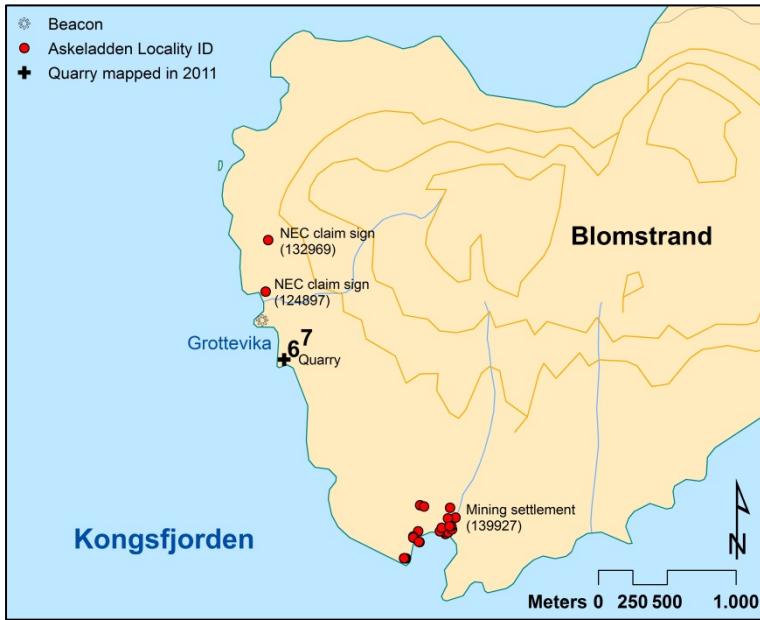
The number of GPR survey grids was dependent on the time spent on site, which in turn dependent on weather and ice conditions as well as transport arrangements

between Ny Ålesund and Blomstrand. The positioning of the grids was guided by previously known historical quarry and borehole locations (Appendix A1.2). Ultimately, seven GPR survey grids were laid out in such a way as to allow for the best comparison of historical information and subsequent GPR data (Figs. 7 and 8). The most relevant historical data that was known prior to the fieldwork has been summarized in Appendices A1.3 and A1.4.



**Fig. 7** GPR survey grids 1 to 5. Grid 1 was positioned immediately west of the Winter Quarry (1919/20). Grid 2 was positioned south of both the Winter Quarry and Grid 1. The two x's between mark the boreholes B1-68 (left) and B2-68 (right), which were drilled in 1968. Grid 3 was positioned on a marble outcrop near No. 2 Quarry, the x here marking a borehole sunk in winter 1912/13. Grid 4 was positioned immediately west of No. 3 Quarry opened in summer 1912. Grid 5 was positioned immediately

*east of the same. The x's mark a borehole probably drilled in winter 1912/13 (south) and borehole B5-68 sunk in 1968 (north). (Map: F. Kruse.)*

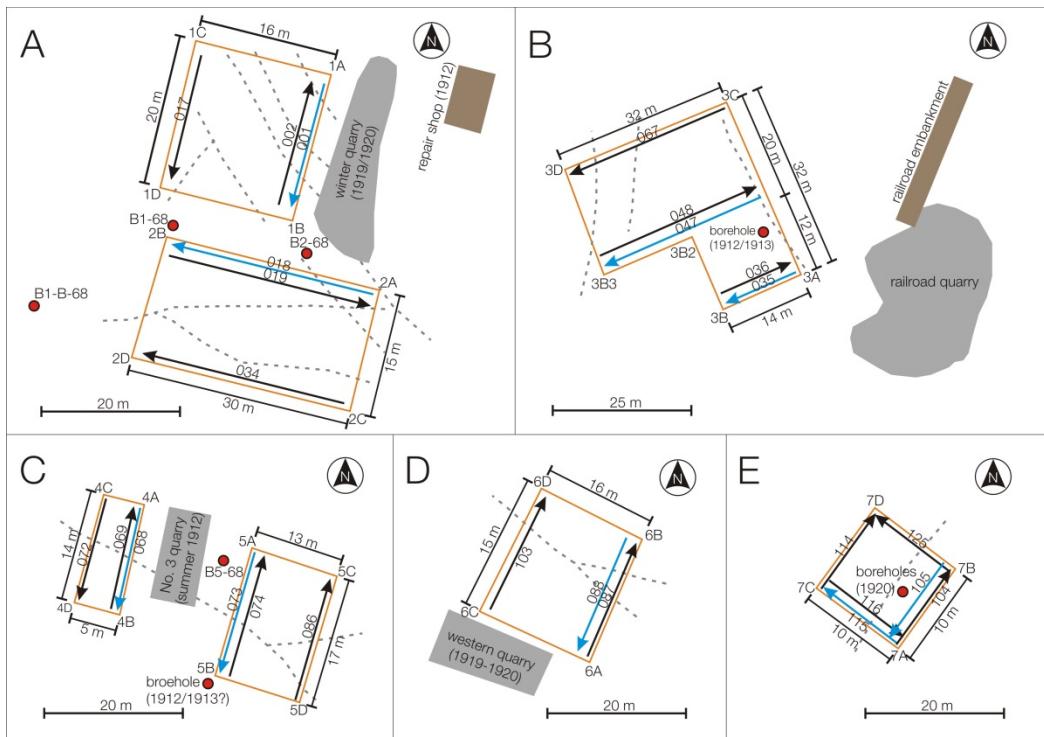


**Fig. 8** GPR survey grids 6 and 7.

*Grid 6 was positioned immediately north of Quarry A13 opened in spring 1920. Grid 7 was positioned on a marble outcrop that comprised two boreholes sunk in summer 1920. (Map: F. Kruse.)*

Additional details of the GPR survey grids 1 to 7 are provided in Fig. 9 below. A spacing of 1m was chosen, with which 125 GPR

profiles were completed. Using Surfer 11 (Golden Software), it was subsequently possible to reconstruct pseudo-3D subsurface models visualizing weakness zones in the marble (e.g. Grandjean & Gourry 1996; Godio et al. 2003).

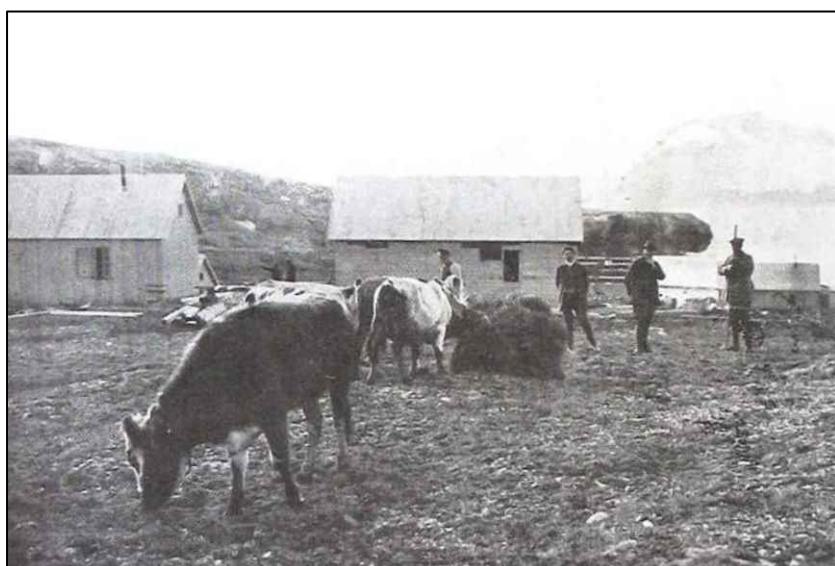


**Fig. 9** Details of the seven GPR survey grids. A spacing of 1m was used, and 125 profiles were completed. (Figure: B. Koster.)

To give an indication of the raw data collected, a contact sheet of all 125 profiles has been included in Appendix 1.5. General GPR data processing was then carried out with ReflexW V7.5 (Sandmeier Scientific Software) and included static correction, back-ground removal, gain adjustments, and velocity adaption for time-depth conversions. The latter was based on a hyperbola analysis where such features were present. Additionally, we used characteristic velocities based on the subsurface material, which in this study is marble (Grandjean & Gourry 1996; Neal & Roberts 2000; Neal 2004; Sambuelli & Calzoni 2010). A contact sheet of the processed images is included in Appendix A1.6. Cracks and faults were detected due to hyperbolic features and abruptly shifted continuous reflectors in the data (e.g. Grandjean & Gourry 1996; Godio et al. 2003; Sambuelli & Calzoni 2010). For some grids, the GPR data can partly be correlated with quarries opened by the Northern Exploration Co. in the early 20<sup>th</sup> century in order to verify and trace the detected cracks and faults. Photo documentation, study area description, and levelling of the study areas were also carried out in the field. Appendix 2 comprises a full photographic record of the fieldwork. Additionally, historical boreholes were calibrated by handheld GPS to compare historical borehole logs with GPR data at these locations.

*Vegetation survey in the former mining settlement, conducted by M. Loonen*

It was known from historical sources that the Northern Exploration Co. had imported livestock for the provision of fresh meat. Pigs were present on site in summer 1912, the last of that lot being slaughtered in December, and cattle was landed in June 1913 (Booth 1913). The photograph below (Fig. 10) was taken at the back of the settlement, looking southeast, probably prior to the construction of the storehouse. Dogs were kept for company, too. Humans, pigs, cows, hay, and to a lesser extent dogs may have had a measurable impact on the local vegetation.



**Fig. 10** Cattle attempting to graze at the back of the mining settlement on Blomstrand. They are also being feed hay. (Source: Barr et al 2011, 103.)

Independently of Kruse and Koster, Maarten Loonen visited the former mining

settlement on Blomstrand on a number of occasions between June and August 2014. On these occasions, he studied the local vegetation as a component of the terrestrial ecosystem. ‘Local’ not being strictly defined, it loosely refers to the vicinity of the upstanding houses as well as the barrack and storehouse foundations at a radius of +/- 10m.

At the beginning of the season in June, Loonen erected several pairs of chicken-wire vegetation exclosures (50cm x 50cm x 50cm) around the former settlement. Their locations are marked on the map in Appendix A3.1. The vegetation exclosures have the function of preventing any grazing and trampling of the vegetation by ‘exclosing’, for example, geese and reindeer (Fig. 11). The exclosures were placed next to (but not on) selected barrack entrances, and their controls were positioned approximately 6m away. In these exclosures, labelled A11, A12, A13, A14, A15, and A17, production was measured on grass tillers at the end of the season on August 4, 2014. Thereafter, the installations were removed without leaving a trace in the field.



**Fig. 11** Reindeer passing by an inconspicuous chicken-wire vegetation enclosure, emphasising the effectiveness of the temporary installation. (Photo: B. Koster.)

On July 12, 16, and 20, 2014, Loonen additionally carried out visual surveys of the unexclosed vegetation in the mining settle-

ment in order to describe the local plant assemblages and to map any newly appearing species. He took small samples of these plants for identification and DNA-barcoding.

As this was a pilot study and time was limited, the quarries, the railway embankments, and other zones of industrial activity were not studied this year.

#### *Reconnaissance dive in Peirsonhamna, conducted by M. Schwanitz*

A reconnaissance dive was conducted in the small bay of Peirsonhamna by Mr Max Schwanitz and a team of divers of the Alfred-Wegener-Institut (AWI) based at Ny Ålesund between June 24 and July 10, 2014. The approximate position of the natural harbour is 78°57'41.06"N and 12°2'38.83"E (Fig. 4). It is roughly circular, measuring between 250m and 300m both in east-west direction and in north-south direction. Depending on the state of the tide, the maximum water depth is between 6m and 7m. It opens into Kongsfjorden to the south.

The team investigated Peirsonhamna on four occasions, completing a total of eight dives in accordance to the GUV regulations “Einsatz von Forschungstauchern” (BGR / GUV-R 2112, issue 2011). The divers made use of an anchoring vessel and a lifeline. The dive times were between 27 and 53 minutes. The maximum depth was 6.2m.

Finds were marked by small buoys and ground weights. Subsequently – when possible – they were photographed, measured, and occasionally drawn.

Mr Schwanitz provided a detailed report in German, which has been added in Appendix 4.

*Newly recorded archaeology on Blomstrand, conducted by F. Kruse*

While the planned interdisciplinary site work was progressing, Kruse took the opportunity to build on the archaeological knowledge of the former mining settlement and quarries as indicated in Figs 4 and 5 above. By means of a walkover, she was able to confirm the majority of the observations and interpretations of the LASHIPA Project in 2008 and newly recorded additional archaeological features, thereby creating a more comprehensive image of the site and its site formation processes. Furthermore, Kruse and Koster took time away from the GPR survey to ascend Ingensfjellet, Blomstrand’s highest peak at 383m AOD and rounded the island on its west side. The hike served the purpose of mapping any material remains not listed in the Askeladden database, thereby populating the archaeological landscape. Any documentation pertaining to newly recorded archaeological features has been included in Appendix 5.

Kruse also experimented with a metal detector. She had not asked *sysselmannen* for permission to do this and hence none had been given. While metal objects could thus be located non-intrusively beneath the surface, it was strictly forbidden to dig them up and identify them. So the point of metal detecting was primarily one of testing the method under Arctic circumstances as a useful tool to identify specific areas of metal-related activities. This befits a landscape approach to Svalbard archaeology.

Kruse first attempted a metal detector survey on the beach in Peirsonhamna. This is best done at the lowest tide and by working parallel to the shore, not at an angle. If the tide is going out, one can start at the top of the beach and follow the water out. If the tide is coming in, one can start at the water’s edge and work landwards. Coloured survey flags are suitable for marking locations that give off signals. They are handy for marking ‘spot finds’, and they are equally handy for probing the concealed edges of large structural metal. In addition, they are very visible in photographs, the only recording of the detected locations that was done on this occasion in light of the disallowed dGPS. Where structural metal needed to be ‘followed’, wooden toothpicks were used: they do not give off a signal themselves and are short enough to survey over the top of. A subsequent ‘joining of dots’ reveals the extent of the item (Fig. 12).



**Fig. 12** Toothpicks were used during non-intrusive metal detecting in Peirsonhamna in order to trace the extent of concealed structural metal. (Photo: F. Kruse.)

Limited time and an unexpected overload of signals in Peirsonhamna led to the abandonment of the first attempt. A second effort was made and completed on a 'less

'busy' beach in the first small bay to the east of Peirsonhamna. No metal detecting was carried out in the former mining settlement and industrial areas. These were assumed to be 'too busy' to give useful results.

#### *Archival research in Great Britain, conducted by F. Kruse*

Strictly speaking, the fieldwork and the archival research in the UK occurred separately, but it makes sense to combine and include the findings and preliminary interpretations of the latter in this report, even if it does swell the pages. By means of introduction, the author has made an effort to repeat some of the many known historical photographs in Appendix A6.1.

"Marble at Fault" being a multi-phased project, Kruse actually intended continued archival research in both the UK as well as North America. Firstly, her documentary leads suggested that another reason for the company's failure may have been a depression in the British marble market caused by significant changes as a result of the First World War, particularly a governmental subsidy of affordable housing development rather than luxury building. Secondly, machinery remaining on Marble Island today was manufactured and supplied by the US firms Sullivan and Ingersoll-Rand, which proves the company's efforts in the direction of America. This finds verification in historical documents that also tell of a directorial visit to New York in 1912 in order to size up the American marble market, enlist the help of marble specialists here, and enrol further investors. Archival research in this direction could potentially reveal the reasons why subsidiary companies, which were envisaged to carry out actual mining, never came forward.

Most importantly, the original hand-written manuscript, notebook, and diary of Herbert Leech, marble manager for the first time in summer 1919 (and then again in summer 1920), survive in Toronto, Canada, awaiting auction for the phenomenal sum approaching \$9.900. This sum is

probably related to a mention of Shackleton, who is of great interest to collectors, although he never actually arrived on Spitsbergen. Kruse hoped to obtain the cooperation of the current owner and gain access to these papers in order to tap into their academic potential. Unfortunately, the owner felt that he had nothing to gain from such a cooperation. Kruse never saw the papers, and their value for this research remains unknown.

After the fieldwork in autumn 2014, Kruse conducted additional archival research in Great Britain. Following up leads arising from her previous study, she visited the following repositories:

- The National Archives of Scotland, Edinburgh
- The National Mining Museum of Scotland, Newtongrange
- The North of England Institute of Mining and Metallurgy Library, Newcastle-upon-Tyne

In addition to consulting a broad but limited range of primary documentary sources, she met with Mr David Newman, a local historian in Goldhanger, Essex, who provided valuable information about Ernest Mansfield and others who had once resided in the village while at the same time being instrumental to the Northern Exploration Co. and to the marble quarries on Blomstrand. Moreover, she accessed *The Times*, *The Gazettes*, and *Hansard* (the UK parliamentary record) online. The material relating to historical marble quarrying thereby discovered was sparse, but it opened new lines of enquiry and occasionally led to unexpected results.

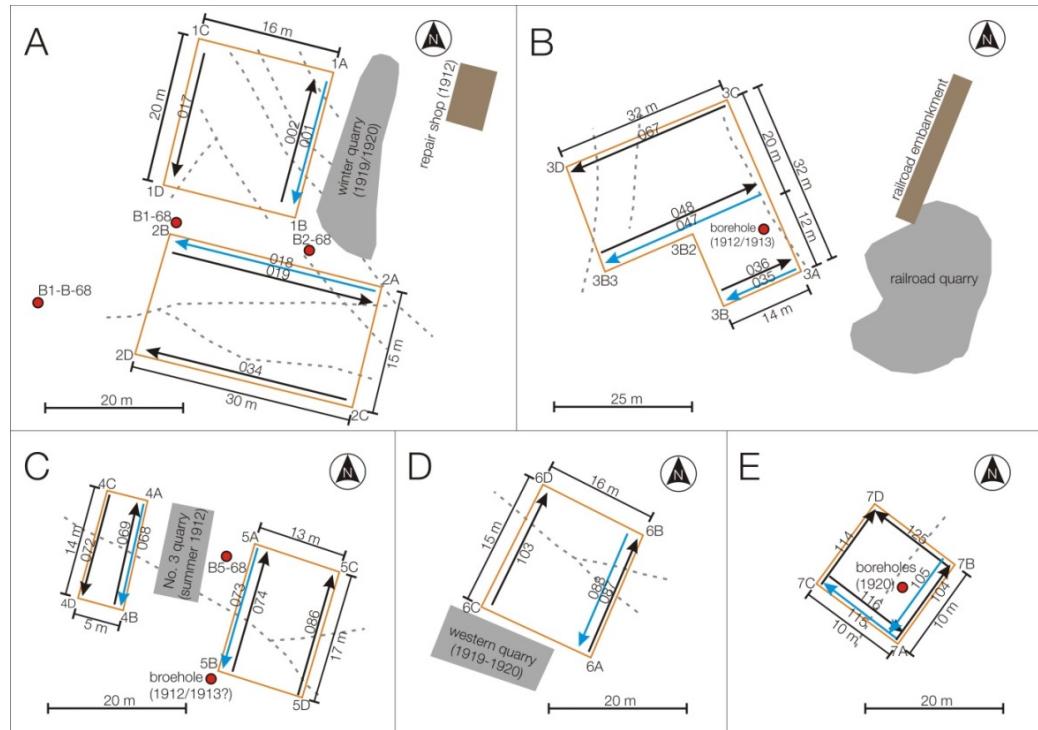
At the time of writing, Kruse became aware that an important contemporary text had become available online. In 1909, Renwick published an extensive account of marble and marble working around the globe. Unfortunately, Kruse did not have time to work through the text and include any relevant aspects in this report. A quick glance, however, revealed that Renwick apparently did not know about the marble quarries at Fauske in Norway. This and other historical details of marble and marble workings are included in Appendix 6.

## Results

### Ground-penetrating radar (GPR) survey

The GPR survey generated a total of 125 GPR profiles with lengths between 10m and 40 m in seven different survey grids. Survey grids 1 to 7 were located close to known historical quarries and/or boreholes (Fig. 13). All GPR measurements were acquired on outcrop surfaces of the bedrock, i.e. not on any unconsolidated overburden overlying the marble, to ensure direct coupling with features in the subsurface. The GPR profiles were mainly recorded at right angles to continuous cracks, faults, or fracture zones that were observed on the ground surface or in historical quarries as indicated in Fig. 13. Due to particularly strong continuous reflectors visible in the raw data of Grid 7, GPR profiles were carried out in both perpendicular and parallel directions. The weather conditions on the days prior to and during the survey were arid and mostly sunny with temperatures between -8°C and +5°C. The survey grids and surrounds were free of snow, ice, or water retention.

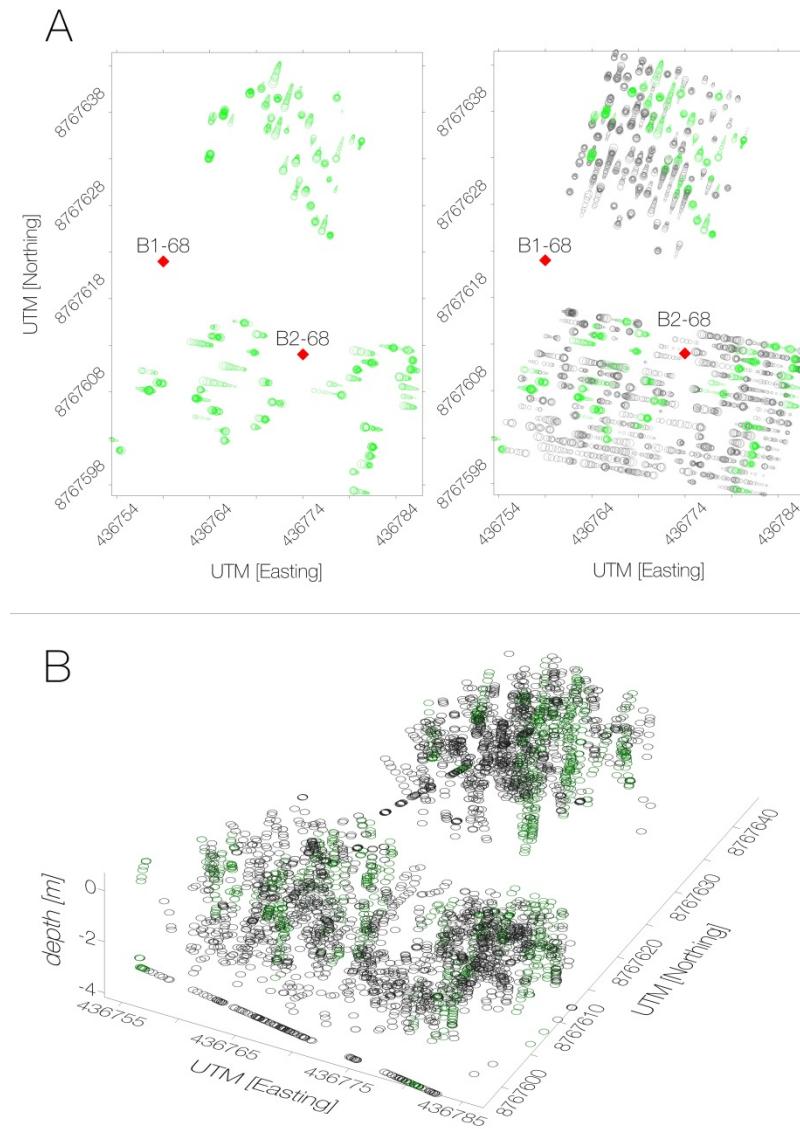
The main hyperbolae velocities in the GPR data range between 0.09 m/ns and 0.10 m/ns, which is similar to electromagnetic wave velocities given in literature for marble rocks (e.g. Grandjean and Gourry 1996, Neal and Roberts 2000, Neal 2004, Sambuelli and Calzoni 2010).



**Fig. 13** Settings of survey grids 1 to 7 (orange outlines with correspondingly numbered corners), any adjacent quarries (grey areas) and boreholes (red points), and observed cracks on outcrop surfaces (dashed lines). The black arrows indicate zigzagging GPR profiles, of which the blue ones indicate the start of the survey as well as the main direction for processing. (Figure: B. Koster.)

Survey grids 1 and 2:

The area under investigation in survey grids 1 and 2 is located to the west and southwest of the Winter Quarry opened in winter 1919/20 (Fig. 7). In this quarry, a fault and a natural slip surface were observed (Fig. 6; Fig. 13A; Appendix A1.4).



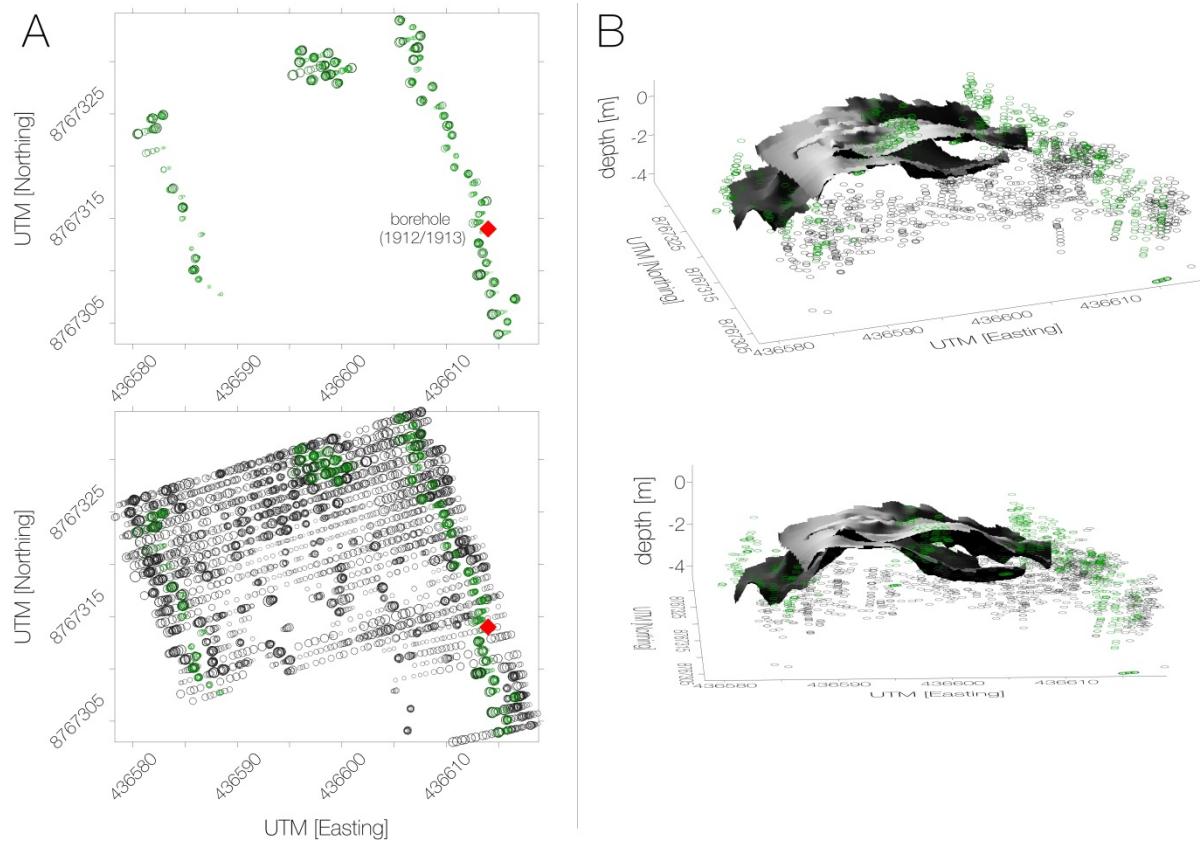
**Fig. 14** Locations of observed crack or fault features within the subsurface of survey grids 1 and 2 as well as two boreholes of 1968 (red rhombi). (A) Cracks and fractured zones visible at the surface (left, green circles) and cracks and fractured zones only detected within the subsurface (right, grey circles) using GPR (generally, the size of the circles increases with depth to ~4m below the surface); (B) Grids 1 and 2 visualised in a pseudo-3D model (colours as before, while point size is constant). (Figure: B. Koster.)

The grids were surveyed in different directions due to the NW-SE trending of the fault and with the objective to visualise additional structures as effectively as possible (Fig. 14A). The fault zone can be traced throughout the whole of the GPR data for Grid 1 as well as Grid 2 from NNW to SSE and approaching the maximum survey depths of ~4m (Fig. 14B).

Abruptly shifted reflectors in the GPR data as well as small vertically aligned hyperbolae reflections with velocities around 0.09m/ns indicate fracturing of the marble. In some parts, the cracks are branched in various directions, which is not visible from the ground surface but detectable by GPR. In this survey area, a lot of vertical cracks that are not visible from ground surface (starting at a minimum depth of 0.4m below the ground surface) were observed in the GPR data. These cracks are aligned and branched in several directions emerging chaotic fracture structures. Within both survey grids, only small parts are free from cracks and faults fracturing the marble.

### Survey grid 3:

The area under investigation in Grid 3 is located ~300m to the SSW of Grids 1 and 2 at the end of the former railway embankment and incorporates a historical borehole drilled and cemented in winter 1912/13 (Fig. 7; Fig. 13B; Appendix A1.3). Interestingly, the borehole had been sunk into one of two linear cracks visible on ground surface along the eastern and western edges of the survey grid. Between these cracks, homogenous conditions of the marble could potentially exist. The GPR survey direction was thus chosen to be perpendicular to the linear cracks on the surface. The two main cracks at the east and west edge of the survey grid clearly show in the GPR data up to ~4m depth below ground surface (Fig. 15A). In the northern part of the survey grid, the GPR also detected several small vertical cracks in the subsurface.

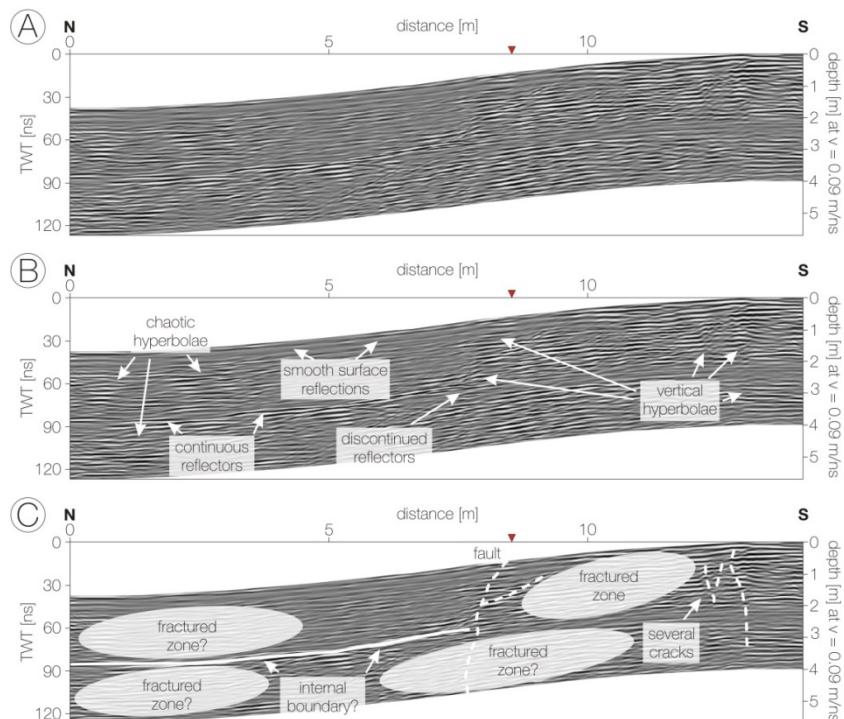


**Fig. 15** Locations of observed crack or fault features within the subsurface of Grid 3 as well as a borehole sunk in 1912/13 (red rhomb). (A) Faults and cracks traced from ground surface (greenish points) and detected fractured zones and folds only within the subsurface (greyish points) using GPR (in general: small points = near ground surface; bigger points = up to 4m depth below surface); (B) Similar survey grid visualised in a pseudo-3D model with illustration of observed multiple folds in the marble bedrock from slightly different viewing directions (colours of points indicate same characteristics as previously mentioned while point size is constant). (Figure: B. Koster.)

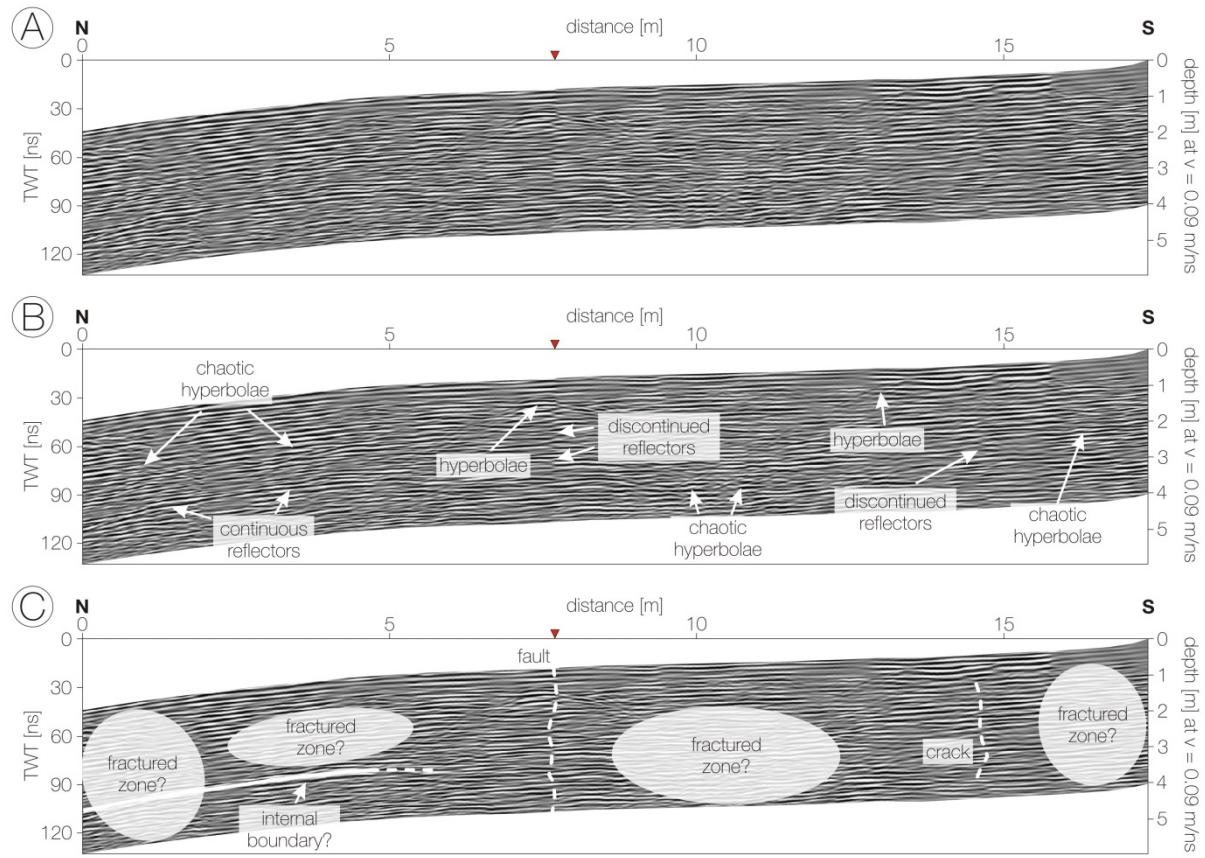
Unexpectedly, the GPR data indicate two blended folds with several branched cracks (Fig. 15B). The top of the upper fold is located only ~0.3m below ground surface. The folds are characterised by relatively clear and continuous reflectors with sporadic linear adjacent hyperbolae reflections (velocities ~0.09m/ns). Hence, the marble within Grid 3 is seriously fractured due to the folds and adjacent fracture zones as well as several scattered vertical cracks.

### Survey grids 4 and 5:

The areas under investigation in survey grids 4 and 5 are located only ~30m NE of grids 1 and 2 on either side of the historical No. 3 Quarry opened in 1912 (Fig. 7; Fig. 13C; Appendix A1.4). There is also a historical borehole sunk in winter 1912/13 (Appendix 1.3) and another one from 1968 (currently no known record). The GPR survey was carried out parallel to the direction of channeling (quarrying by machine) and perpendicular to a long crack visible on the marble's surface. The GPR data in both areas are slightly overdriven, and cracks as well as fault features are challenging to observe. The cracks visible on the surface (marked) can be followed by several small hyperbolae as well as displaced continuous reflectors, which most likely indicate a fault (Figs. 16 & 17). The depth of this feature can be observed up to the lower end (~4m depth below ground surface) of the GPR data. Furthermore, a smooth continuous reflector at ~2m depth below ground surface is observed in northern part of Grid 4. This feature possibly indicates an internal boundary or a dislocated surface within the marble. In some GPR profiles, smooth reflection patterns with several small hyperbolae are observed. These structures may indicate chaotic fracturing areas in the subsurface. It is not clear whether these belong to crack features near the ground surface or possibly internal alteration/weathering of the marble. Beside the main fault within survey grids 4 and 5, there are several small (vertical) fracturing features visible. It remains challenging to interpret cracks at both investigation areas due to the slightly overdriven data quality.



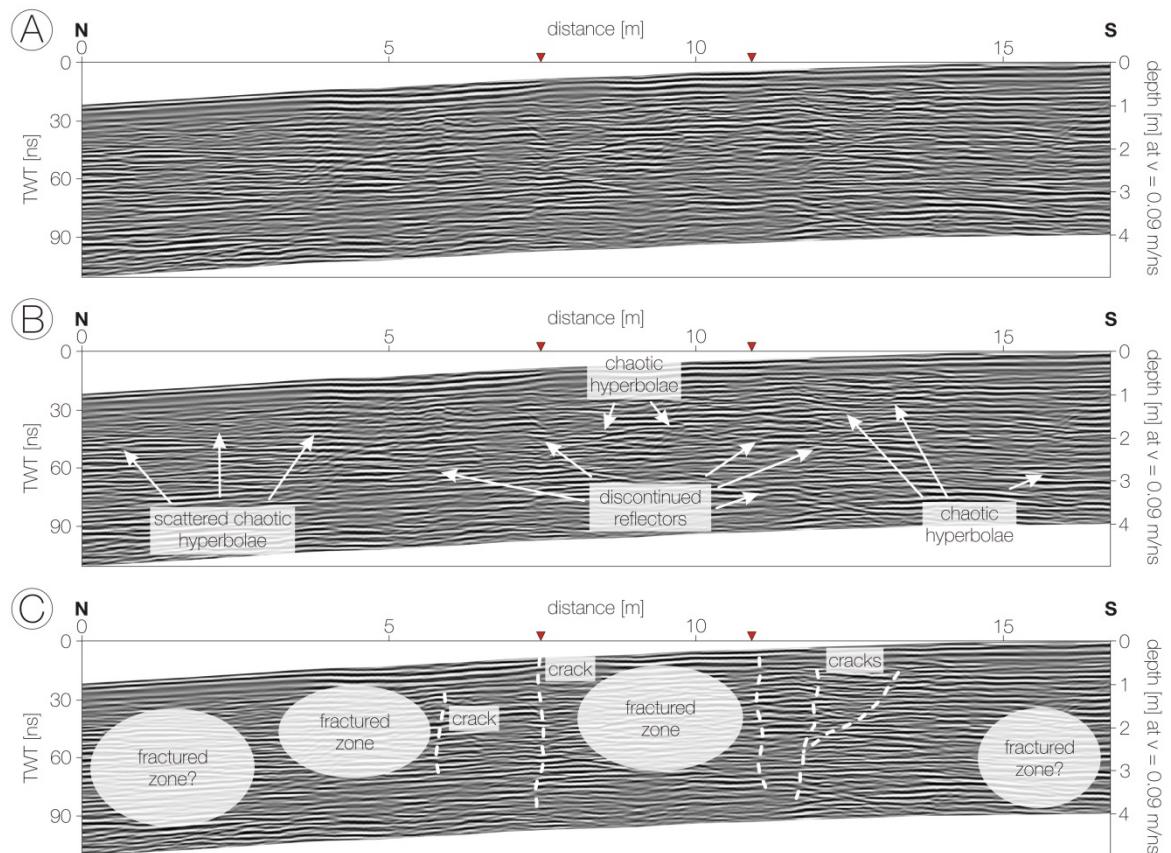
**Fig. 16** GPR profile 69 recorded within survey grid 4: (A) processed GPR profile, (B) processed and analysed GPR profile and (C) interpretation of the GPR profile. (Figure: B. Koster.)



**Fig. 17** GPR profile 78 recorded within survey grid 5: (A) processed GPR profile, (B) processed and analysed GPR profile and (C) interpretation of the GPR profile. (Figure: B. Koster.)

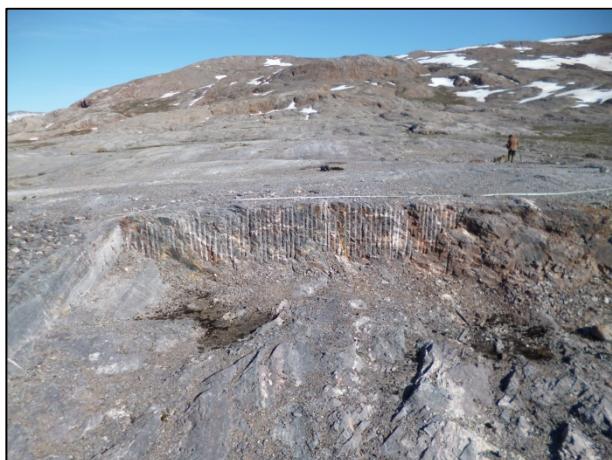
### Survey grid 6:

The area under investigation in Grid 6 is located ~1.5km NW of the other survey grids and next to a historical quarry known from a single historical source only as Quarry A13 opened either in winter 1919/20 or in spring 1920 (Fig. 8; Appendix A1.4). In the field, we called it the Western or Lighthouse Quarry due to the modern beacon nearby. The survey grid was positioned at right angles to the direction of mining but also perpendicular to a linear crack on the marble's surface (Fig. 13D). The GPR data comprise several discontinued reflectors as well as several single hyperbolae reflections. Linear surface cracks marked in the GPR data can be traced by slightly shifted reflectors in the GPR data as well as aligned hyperbolae reflections up to ~3.5m depth below ground surface (Fig. 18). Further vertical cracks can be linked to linear hyperbolae reflections or shifted discontinued reflectors in the marble. Altogether the marble in this investigation area seems not as affected by damaging of the marble due to fractures and cracks, although some fracturing of the marble in the adjacent surface works can be observed.

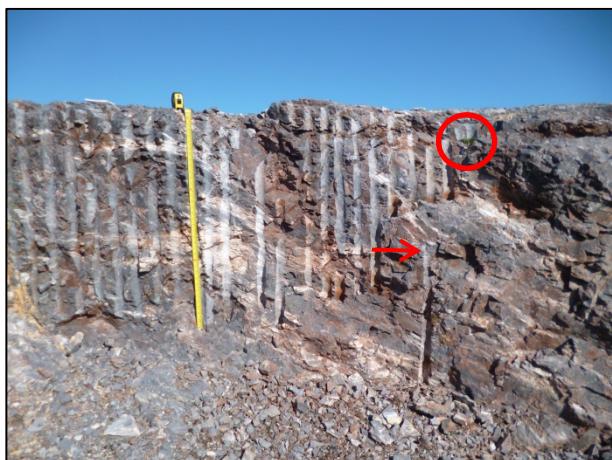


**Fig. 18** GPR profile 102 recorded within survey grid 6: (A) processed GPR profile, (B) processed and analysed GPR profile and (C) interpretation of the GPR profile. (Figure: B. Koster.)

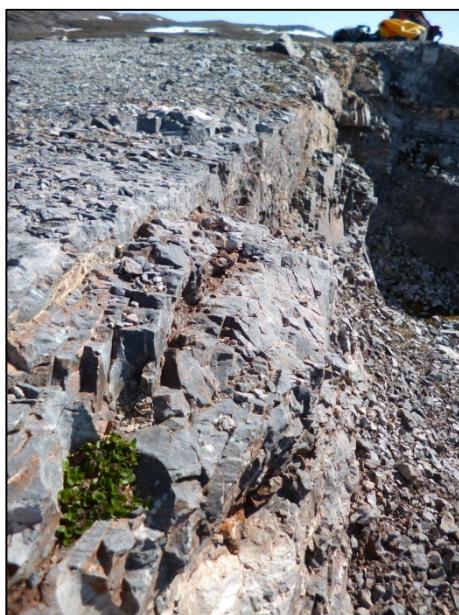
A close inspection of the shallow surface works were carried out and showed what happened when a line of drilled holes (a method of channeling) met with a natural fracture (Figs 19a-c).



**Fig. 19a** Tool marks in Quarry A13. (Photo: F. Kruse.)



**Fig. 19b** The circle indicates a plant that grew at the point at which the line of holes was stopped by the nature feature and abandoned. The arrow marks a borehole brought forward from the original line, but drilling was not commenced from here. (Photo: F. Kruse.)



**Fig. 19c** A plant grew at the point at which the line of holes was stopped by the fracture or fault and abandoned. (Photo: F. Kruse.)

In addition, the depths of individual holes were measured to get an idea of the effort that went into drilling them (Fig. 20).

Hole	Depth	Hole	Depth										
1	17	8	67	15	83	22	82	29	92	36	56	43	90
2	49	9	75	16	87	23	76	30	68	37	62	44	106
3	45	10	75	17	n/a	24	89	31	85	38	71	45	90
4	53	11	n/a	18	n/a	25	n/a	32	85	39	84	46	90
5	55	12	68	19	90	26	95	33	88	40	84		
6	58	13	n/a	20	n/a	27	94	34	69	41	84	Total	2957
7	62	14	87	21	n/a	28	93	35	64	42	89		

**Fig. 20** Individual and total depths (in mm) of holes in Quarry A13. The bottom of some holes could not be observed and the last attempts were not taken into consideration, the total effort was therefore several meters larger than 29.57m.

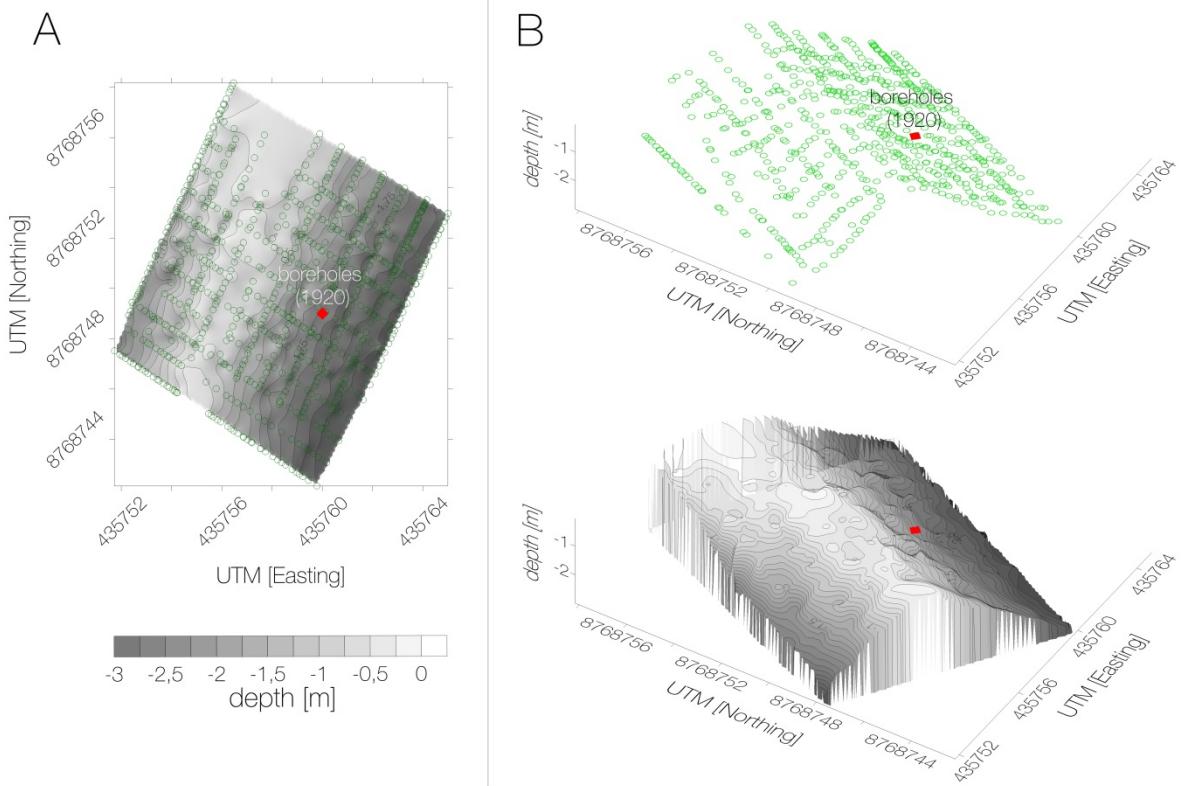
#### Survey grid 7:

The area investigated in Grid 7 is located ~40m to the N of Grid 6 and Quarry A13. It comprises two historical boreholes sunk in summer 1920 (Fig. 8; Appendix A1.4). Leech (1920) described one as a 3-inch hole (7.6cm) and the other 4-inch (10.2cm) and that both had been drilled to 7 feet (2.13m), where the marble crumbled due to a suspected subsurface fault. It was surprising, however, that the holes were found to be separated by a few centimeters only (Fig. 21). The smaller one was found to be 2m deep, the larger 1.9m, which is close enough to the depths stated. The level of liquid water was recorded at 1.47m bgl.



**Fig. 21** Leech (1920) described two boreholes being drilled in summer 1920. These were found to be separated by a few cm only.  
(Photo: F. Kruse.)

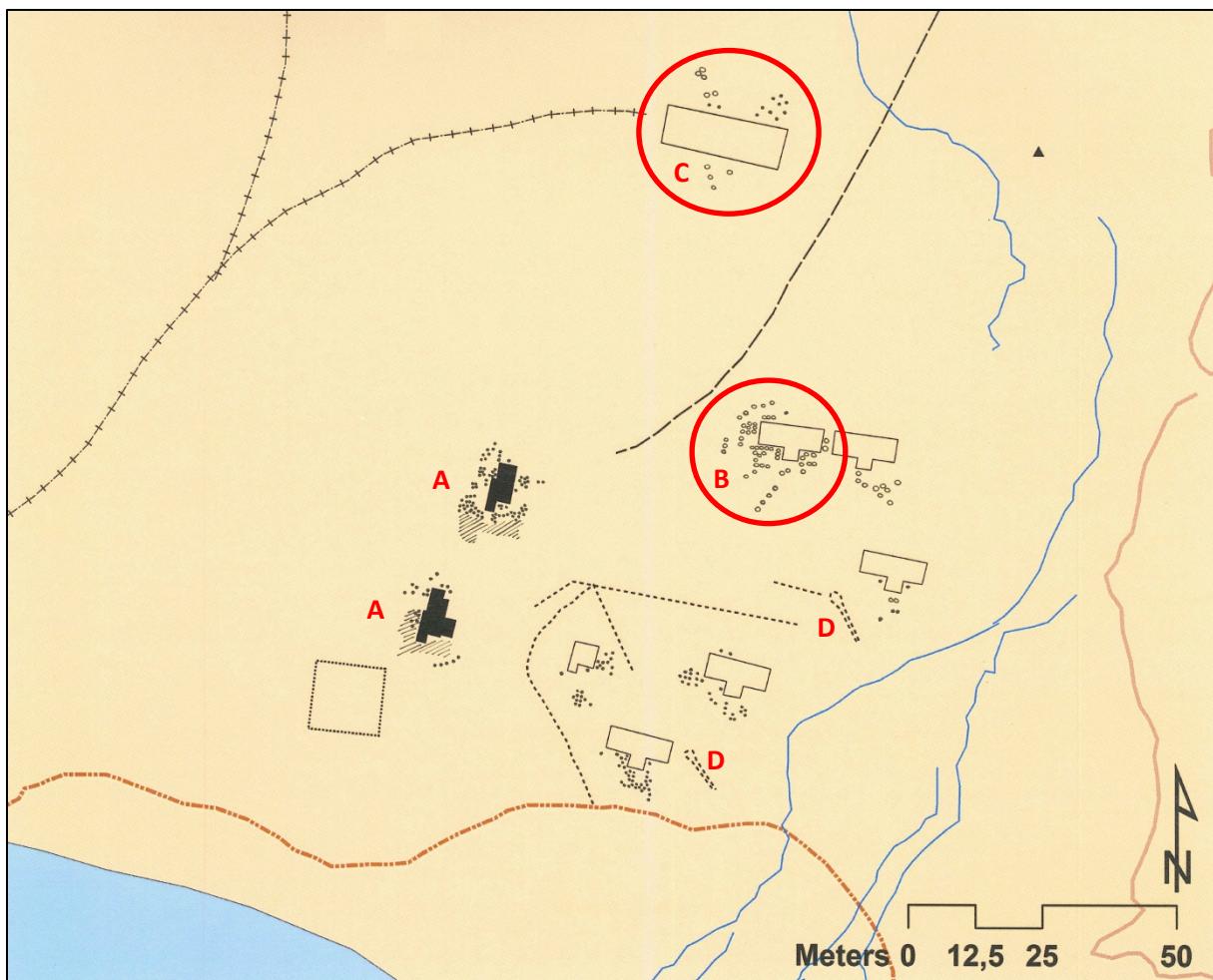
A linear crack running SW-NE could be seen at the surface (Fig. 13E). GPR data reveals a strong continuous reflector in both the perpendicular and the parallel profile. These reflectors are accompanied by further hyperbolae ( $v = 0.09\text{m/ns}$ ) that are chaotically distributed alongside the continuous reflector. Pseudo-3D visualization of picked GPR data (Fig. 22) indicate a fold structure with its fold axis near the surface (~ 0.2m depth below ground surface) and is most likely the reason for the linear crack observed at the surface. It is obvious that the marble in this survey grid is fractured due to the present fold structure with a surrounding fracture zone with a diameter of ~0.5m.



**Fig. 22** Location and orientation of observed fold within the subsurface of survey grid 7 as well as location of two boreholes (red rhomb): (A) Contour map of the observed fold with data points (greenish points; constant point size in different depths) as well as location of boreholes (red rhombi) within the survey grid; (B) Similar survey grid visualised in a pseudo-3D model: (top) 3D data points (constant point size) and (bottom) 3D contour model. (Figure: B. Koster.)

### Vegetation survey

At the time of writing, it is possible to include a map of the mining settlement indicating the locations of newly appearing plant species (Fig. 23).



**Fig. 23** The results of the visual vegetation survey in the former mining settlement show newly appearing plants (dots, circles = individual plants, shading = high density of plants). (Data: M. Loonen. Map: F. Kruse.)

It is clear from the map that newly appearing plants can mainly be found in the immediate vicinity of former and current buildings, in particular around former and especially current doorways, as opposed to more open areas or the vicinity to water. The assumption is that newly appearing species found their way here as seeds on the shoes or in the clothing of visitors or in animal feed such as hay. The highest densities occur around the upstanding buildings that used to be managerial accommodation (A). These high densities are thought to be the compound result of historical activities, cruise tourism, and overnight stays, which are still possible in the huts. Due to ongoing site formation processes, these areas do not lend themselves to temporal analysis.

The question arises if anywhere on site lends itself to historically-relevant analysis, since visitors have been and are free to go anywhere they please, and the potential of continued seed introduction exists across the whole site if not island. However, some places are more attractive to visitors than others and the simple wooden platforms are thought to rate extremely low in this list of attractive places. Therefore, the pattern of newly appearing species around the doorways of the former barracks is thought to be a historical pattern. The plants are likely to have been brought by the builders and miners.

A conspicuous concentration and spread can be seen around the particular former barrack behind which the historical photograph of the cows was taken (B). Again, there is no specific reason why cruise tourists and overnight visitors should linger here. So the observations support the notion that cows, other livestock, and hay were kept in this area. And that their manure may have enriched the soil and enhanced production. That has yet to be confirmed.

The former storehouse in which the historical channelers and other machinery have now been gathered (C) is, on the other hand, a very poignant location and immediately appeals to many visitors. Being a hotspot of ongoing tourism, it is impossible to say much about the newly appearing plants here.



**Fig. 24** A stone-lined drain down to the stream. (Photo: D. Avango.)

It is noticeable that former toilets are not immediately obvious on the site. From historical photographs, the workers' lavatories are known to have been incorporated into the barrack doorways, and a similar

construction probably existed in the managerial houses. Lavatories are again interesting from an 'enriching the soil' perspective. Even if they were indoor toilets, the buckets must have been emptied somewhere, and it was thought that the features marked D could have been stone-lined drains for this purpose. However, they were remarkably devoid of grasses or any other newly appearing plants. To supplement the visual survey, the measurements of grass tillers in the vegetation exclosures and in nearby unexclosed areas have been provided in Appendix A3.2. The analysis of the vegetation survey had not yet been completed.

### *Reconnaissance dive*

The team of divers discovered an overseable number of metal objects at two of four dive locations in Peirsonhamna. Below the crane, they found a small metal wheel (probably a machine part), a length of rail, a metal rod to tie rails together, a tool (probably a crowbar), and two metal plates. Below the Norwegian fishery station, they recorded a small hoist, a metal bracket to pin wooden sleepers together, and a non-descript metal object. In the stream delta and in mid-harbour, they saw nothing. Besides metal objects, there were no other forms of clearly visible impacts under water. A full report is provided in Appendix 4.

### *Newly recorded archaeology*

Any newly recorded archaeology has been included in Appendix 5. It comprises a map of features, a list of observations and preliminary interpretations, and a photograph of the calendar from 1968. The map below summaries the results of the walk over and around half of Blomstrand. All archaeological features encountered were mapped (Fig. 25). Besides former industrial features already mentioned in the text, these comprised exclusively fox traps.



**Fig. 25** Map showing the walk over and around one half of Blomstrand, indicating all archaeological remains not previously mentioned in the text. These were exclusively fox traps. (Map: B. Koster.)

The experimental metal detector survey was inconclusive. While the method lends itself to Arctic conditions, permission must be sought to use it properly. The beach in Peirsonhamna could not be

surveyed completely in the time available. The next beach along was small and surveyed completely. There were signs of the recent human presence in Svalbard in the form of washed-up broken plastic as well as two pieces of orange peel and a whole apple. Metal was detected in the form of two nails in a small piece of driftwood and a bullet cartridge. Significantly, they corresponded to the two main activities expected from this: construction and hunting. There is hope for better results in other areas in the future.

#### *Archival research*

New information discovered in the archives as well as on the internet has been included in Appendix 6. This includes repeat photography, the contents of archival sources and their preliminary interpretation placed in a crude timeline, Home Office marble statistics between the years 1902 and 1912, summaries of two company files, and a summary of the environmental impact and diseases of a wintering party in 1912/13.

## **Discussion, conclusion, and future work**

The interdisciplinary archaeological fieldwork that was carried out at the former British mining settlement and quarries on Blomstrand in Kongsfjorden, Spitsbergen, in July 2014 addressed two main questions, which shall be dealt with in turn.

### **1) Why did past attempts to quarry marble on this Arctic island fail?**

The assumption that permafrost had a negative effect on the marble is simply wrong. A focus on purely geological factors is inexcusably short-sighted. In industrial archaeology and mining history, one must make a habit of considering a combination of geological factors, managerial and/or directorial flaws, and market forces at work. One or more of these may weigh more heavily than the others.

Regarding potential geological factors, a GPR survey was carried out in order to assess the quality of the marble that had been explored and worked historically. The survey established seven grids (125 profiles). Grids 1 and 2 substantiated the considerable fault zone clearly visible in the Winter Quarry of 1919/20, which had for that obvious reason been abandoned in 1920 – the data showed that further work in the immediate vicinity would have been uneconomical. Grid 3 was close to No. 2 Quarry opened in 1912 and incorporated a borehole sunk in 1912/13, from which only rubble was then retrieved. The borehole lay on a visible crack. The crack was caused by an underlying fold, along the limbs of which extensive fracturing had occurred – working would probably have been uneconomical. Grids 4 and 5 lay on either side of No. 3 Quarry opened in 1912, about which the marble manager continued to be enthusiastic in 1920. The smooth continuous reflector at a depth of ~2m, practically surface rock, might or might not have been disruptive during working – the results remain inconclusive. Grid 6 to one side of Quarry A13 opened in 1920 displayed some surface cracks that seemed to discontinue at depth – the marble was seemingly sound, but Grid 7 lay uncomfortably close by. Grid 7 comprised two boreholes sunk in 1920, which were known to have hit a fault that was, however, not thought to be worrying. In fact, the grid revealed a substantial fold with a 50-cm fracture zone around the limbs – this may have been potentially workable if any quarrying were orientated appropriately. To make the most of the GPR results, they will in the near future be discussed with marble quarry specialists.

In light of the above, we can currently say that we were able to detect several cracks, faults, fractured zones, and even (multiple) folds on the archaeological scale, as opposed to a geological one, to a depth of up to ~4m below ground level using GPR with only the 400 MHz antenna instead of a range of three antennae. The orientation of cracks, faults, and folds varies strongly within all survey grids. Therefore, not all features may be related to major thrust faults and folding on

Blomstrand. However, the majority of cracks and faults in the marble were not recognisable from the ground surface, which addresses one of the main issues at the heart of the GPR investigations.

Approximately a century ago, the different actors involved in the exploration and quarrying of the marble, irrespective of the nature of their ‘loyalty’ to the Northern Exploration Co., were most likely not able to detect the amount of “damage” within the marble by means of boreholes and shallow surveys. Structural information (like fractured marble) might have been noted in historical borehole logs but in a different way from modern technical capabilities and due to missing information about detailed subsurface architecture.

Present geological or tectonic maps still do not show faults in the areas where the mining company tried excavating the marble, which is possibly due to the large scale of geological mapping of Blomstrand. A lot of faults are assumed to be related to isostatic uplift as we were able to observe several fresh surface cracks in different orientations. Isostatic uplift has been active since the Late Weichselian (e.g. Lehman & Forman 1992, Lauritzen 2006, Ingólfsson and Landvik 2013) in Kongsfjorden. Detailed geological mapping, especially structural/tectonic information, in the vicinity of former mining areas on Blomstrand could be an additional tool for a better understanding of the subsurface conditions.

In general, the GPR technique seems to be capable of detecting faults and similar features of the bedrock in an Arctic environment. Former studies have already illustrated GPR investigations on marble quarries but under Mediterranean weather conditions (e.g. Grandjean and Gourry 1996, Godio et al. 2003). However, subsurface investigations of the marble of Blomstrand is possible providing excellent Arctic summer conditions (temperatures around 0°C, arid, no snow cover or water detention on the bedrock, no permafrost soil coverage) as well as using the appropriate GPR setup and an investigation-matching antenna frequency (in this study 400 MHz). A lower frequency antenna (e.g. 270 MHz or 200 MHz) could possibly detect cracks and faults even in lower depths, but resolution would be worse (e.g. Neal 2004) and, therefore, smaller cracks and faults might not be visible in the GPR data.

Besides the quality of the marble, managerial incompetence on site may have been another factor. Archaeologically, this may have itself in overspending on superficial structures prior to World War I. As Kruse (2013) has already pointed out, the mining settlement seemed rather impressive in relation to the limited quarrying done, but this may have been part of an advertising strategy to present far-away investors with exciting Arctic photographs and entice them into investing further into this grand scheme. No buildings were erected after the war and little remains of the large radio antenna that was put up, so it may not be immediately obvious whether overspending continued. Away from Blomstrand, however, elsewhere on Spitsbergen, the NEC definitely spent more money than it made

in return. Overspending was a serious flaw, but if the company had actually delivered raw materials in large, profitable amounts, it could yet have been worth it. So overspending was a relative. More importantly, the archival sources point to several crucial things. Firstly, there appears to have been a growing demand for marble prior to the First World War. This would have been a sensible time to invest in the resource. Secondly, however, the diamond coring in 1912/13 had not been successful (sabotage was mentioned, but Booth's own technical abilities were not questioned), yet beautiful solid cores mysteriously appeared in the London office. It is also suspicious that the crucial report by the American marble specialist Minard, who worked on site in summer 1913, can no longer be found. Was it willfully destroyed? This hints at fraud, but it cannot be proven who was responsible. Was it Mansfield? Was it Salisbury-Jones? It certainly appears to have been someone in the field as it seems that the directors truly believed in the soundness and value of their marble. Even when the market crashed after the war and when the Danish Commissioner raised a fee for every acre claimed, the company hung on to Blomstrand. It remained in the possession of the company, until it sold all its assets to the Norwegian Government.

All things considered, crash in the marble market was the main reason for all work being suspended in 1920 – at a point when it had not been proven beyond all doubt whether the marble was or was not workable, let alone profitable. Trying to prove this beyond the GPR survey carried out during the project 'Marble at Fault' is not necessary: since the historical actors had no knowledge of the resource beyond that which is included in these pages; new geological knowledge beyond the reach of the historical works is probably very interesting but loses its historical relevance. However, Minard's report of 1913 or the borehole logs of 1968 could fill the current knowledge gap.

## **2) What was the lasting impact of this industry on the local environment?**

The construction, exploring, and quarrying activities on Blomstrand between 1911 and 1920 created the cultural heritage that is protected by law today. This in itself is an obvious long-lasting environmental impact. Although some people find polar industrial heritage unsightly, it is a reminder of past human endeavour in this location. If a dGPS had been available, Kruse and Koster would have attempted to quantify the volume of earth and rock that had been moved around on site. This would have been the direct impact of construction and quarrying.

The metal detector survey which Kruse tried was meant to delineate subtle zones of metal-related activities, but this failed due to an unexpected overload of signals, i.e. a large number of metal objects in the ground. The question remains how much scrap metal the site actually comprises. It is bound to be a lot. So what is its environmental impact?

In the framework of “Consequences of exploitation”, the vegetation in the mining settlement was investigated by means of a walkover survey and in the form of production on grass tillers. The resultant map clearly indicates the distribution of newly appearing species, mainly grasses, which can be shown to have historical relevance. This pilot study can and should be built on: a comprehensive systematic study should be undertaken across the settlement as well as the industrial areas to map, identify, and qualify all newly appearing species. This has to a certain extent been done in places like Longyearbyen and Ny Ålesund. Unlike these places, Marble Island had a limited ‘life span’ that practically ended not necessarily in 1920 but at the time when the barracks were removed to Ny Ålesund. Having a definite beginning and fairly definite end makes a historical site a better case study for lasting environmental impact of certain activities than an open-ended place, where changes are ongoing. An analysis of the production on grass tillers has yet to show if livestock has caused an enrich of the soil in certain location on Blomstrand.

Besides some large metal objects being found under water, the quarrying does not seem to have had any lasting effects on the coastal ecosystem. It was hoped that rubbish heaps could perhaps be located at the bottom of the cliffs, but this was not so.

The Day Book written by the mechanic David Booth in winter 1912/13 and a mention by Herbert Leech in 1920 that 11 men wintered that time offered an unusual glimpse into the environmental impact of such a group on the marine and terrestrial ecosystems. In itself, the removal of 100+ birds and a handful of seals may not seem significant, but if more historical accounts of this type were known and analysed, a comprehensive picture of the impact of the human presence could over time emerge. It would take a lot of work, but it would be invaluable. It is interesting that Booth does not make a mention of reindeer and polar bears. They had probably been hunted to the extent of being absent from the Kongsfjorden area.

Booth does, however, mention the presence of trappers in the camp. The nature of hunting on the island was briefly addressed by Kruse and Koster during the walk over and around the island. Even the simple plotting of fox traps encountered gives form to an emerging archaeological landscape of hunting and trapping. This should also be pursued further and in better resolution.

While Kruse and Koster were on site, they were regularly visited by a handful of reindeer, three long-tailed skuas, and an Arctic fox. They also observed several common eider ducks with chicks and two barnacle geese on the beach in Peirsonhamna. They discovered a single old eider duck nest. Animals further away than could be identified without binoculars have been disregarded in this tally.

This account of the site’s lasting environmental impact is piecemeal, but it reflects the nature of the sources very well and indicates what kind of questions can and need to be asked of this form of qualitative data. It takes much effort to transform archaeological and anecdotal evidence into an ecologically meaningful account.

## **Outreach**

Good science does good outreach ☺

### *Svalbardposten*

“Marble at Fault” benefitted from the early attention of *Svalbardposten*, probably based on the simple curiosity that the author shared her first name with Frigg Jørgensen of AECO, who had also been granted financial support of the Svalbard Environmental Protection Fund in the 2013. Following a telephone interview with Christian Nicolai Bjørke, the article ‘Frigga får oppfly marmordrømmen’ introduced the project to readers in issue number 47 of November 29, 2013. (Appendix A7.1)

*Svalbardposten* was also instrumental in advertising the workshop in Longyearbyen in January 2014 (see below). A copy of the advertisement, which additionally functioned as a poster to be displayed in strategic locations and online, can be found in the Appendix A7.2.

Upon arrival in Longyearbyen in July 2014, Kruse and Koster again made contact with *Svalbardposten*. Both before and after their fieldwork, they were interviewed by Christopher Engås, resulting in the article ‘Marmoren kan ha skylden’ in Nr. 31 of August 8, 2014 (Appendix A7.3).

The author hopes to uphold the invaluable connection with *Svalbardposten* in order to inform the citizens of and visitors to the archipelago of the important and interesting interdisciplinary archaeological research that is going on in their backyard.

### *Workshop at the Svalbard Museum*

“Marble at Fault” was a multi-phased project. The first phase was a workshop, which took place at the Svalbard Museum in Longyearbyen on Saturday, January 25, 2014. Kruse presented the results of her thesis with a particular focus on Marble Island to interested parties and potential interdisciplinary partners with the goal to raise public awareness of the issues at stake and enthusiasm for the project.

### *SEPF reporting requirements*

“Marble at Fault” being primarily funded by the Svalbard Environmental Protection Fund, the project was subject to some additional reporting requirements. Further to this final fieldwork report, an audience-friendly report (Appendix 7.4) was written, the figures of which were also made into a short PowerPoint presentation (Appendix A7.5). That that project found repeated mention in *Svalbardposten* has been related above.

*Archive location*

All data relating to the research projects “Marble at Fault” and “Consequences of exploitation” are currently being held by Dr Frigga Kruse at the Arctic Centre of the University of Groningen. As far as possible, she will make use of the Research in Svalbard (RiS) database to share the data and disseminate the results of both projects. It is currently unknown if Askeladden, Norway’s database for cultural heritage, will be able to facilitate further archiving.

## References and bibliography

- Aalders, Y., Avango, D., Gustafsson, U., De Haas, H., Hacquebord, L., Hartnell, C., Kruse, F. (2009) *LASHIPA 5. Archaeological expedition on Spitsbergen 27 July – 17 August 2008*, Groningen: Arctic Centre.
- Buggisch, W., Piepjohn, K., Thiedig, F., Gosen, W. von, 1992. A Middle Carboniferous Conodont Fauna from Blomstrandhalvoya (NW-Spitsbergen): Implications on the Age of Post-Devonian Karstification and the Svalbardian Deformation. *Polarforschung* 62 (2/3), 83–90.
- Dallmann, W.K., 2007. Geology of Svalbard. In: Sigmond, E.M.O., Roberts, D. (Eds.), *Geology of the Land and Sea areas of Northern Europe 10. Norges geologiske undersøkelse*, Trondheim, pp. 87–89.
- Ellevold, S., Blomeier, D., Dallmann, W., 2007. Geology of Svalbard. Norsk Polarinstitutt, Tromso, 35 pp.
- Godio, A., Sambuelli, L., Ferrero, A.M., 2003. Geophysical investigation to optimize excavation of an underground marble quarry in Stazzema, Italy. *The Leading Edge* 22 (6), 574–578.
- Grandjean, G., Gourry, J., 1996. GPR data processing for 3D fracture mapping in a marble quarry (Thassos, Greece). *Journal of Applied Geophysics* 36 (1), 19–30.
- Hermansen, P. (2007) *Svalbard Spistbergen guide*, Oslo: Gaidaros.
- Ingólfsson, Ó., Landvik, J.Y., 2013. The Svalbard–Barents Sea ice-sheet – Historical, current and future perspectives. *Quaternary Science Reviews* 64, 33–60.
- Johansen, B. F. (ed. (2011) *Cruise handbook for Svalbard*, Tromsø: Norwegian Polar Institute.
- Johnsen, S., Mørk, A., Dypvik, H., Nagy, J., 2001. Outline of the geology of Svalbard - Short geological review and guidebook. 7th ESF IMPACT Workshop, 11 pp.
- Kruse, F. (2013) *Frozen assets. British mining, exploration, and geopolitics on Spitsbergen, 1904-53*, Eelde: Barkhuis.
- Lauritzen, S.-E., 2006. Caves and speleogenesis at Blomstrandsøya, Kongsfjord, W. Spitsbergen. *International Journal of Speleology* 35 (1), 37–58.
- Lehman, S.J., Forman, S.L., 1992. Late Weichselian glacier retreat in Kongsfjorden, west Spitsbergen, Svalbard. *Quaternary Research* 37 (2), 139–154.
- Neal, A., Roberts, C.L., 2000. Applications of ground-penetrating radar (GPR) to sedimentological, geomorphological and geoarchaeological studies in coastal environments. In: Pye, K., Allen, J.R.L. (Eds.), *Coastal and Estuarine Environments. Sedimentology, Geomorphology and Geoarchaeology*, vol. 175. Geological Society special publication 175. Geological Society, London, pp. 139–171.
- Neal, A., 2004. Ground-penetrating radar and its use in sedimentology: principles, problems and progress. *Earth-Science Reviews* 66 (3-4), 261–330.

- Pirli, M., Schweitzer, J., Paulsen, B., 2013. The Storfjorden, Svalbard, 2008–2012 aftershock sequence: Seismotectonics in a polar environment. *Tectonophysics* 601, 192–205.
- Renwick, W. G., 1909. Marble and marble working. London: Crosby Lockwood and Son.
- Sambuelli, L., Calzoni, C., 2010. Estimation of thin fracture aperture in a marble block by GPR sounding. *Bollettino di Geofisica Teorica ed Applicata* 51 (2-3), 239–252.
- Siggerud, T. (1960) 'The iron occurrence at Farmhamna, Vestspitsbergen', *Årbok 1960*.
- Stange, R. (2012) *Spitsbergen Svalbard. A complete guide around the arctic archipelago*, Huckstorf: Stange.
- Thiedig, F., Manby, G.M., 1992. Origins and deformation of post-Caledonian sediments on Blomstrandhalvøya and Lovenøyane, northwest Spitsbergen. *Norsk Geologisk Tidsskrift* 72, 27–33.
- Umbreit, A. (2009) *Spitsbergen*, Chalfont St Peter: Bradt.

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