REPORT

Norwegian GeoTest Sites (NGTS)

GEOTECHNICAL SITE INVESTIGATION, SVALBARD
FIELD REPORT – PERMAFROST SITE - ADVENTDALEN

DOC.NO. bmDokumentnr
REV.NO. Rev3 / 2018-10-03

Project

Project title:	Norwegian GeoTest Sites (NGTS)
Document title:	Geotechnical site investigation, Svalbard Field report – Permafrost site - Advendtdalen
Document no.:	bmDokumentnr2
Date:	2017-09-27
Revision no. /rev. date:	Rev3 / 2018-10-03

Client

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Contract reference:	RCN project number 245650

for NGTS

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Summary

The NORWEGIAN GEOTEST SITES research infrastructure, with funding from The Research Council of Norway, creates national research test sites facility for geotechnical research.

This report covers the field work on the NGTS Permafrost site performed by SINTEF during the time period March-April 2017 at the Adventdalen site, located in the Longyearbyen area at the old airport/Aurora research station.

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Review and reference page

1 Introduction

The NORWEGIAN GEOTEST SITES research infrastructure, with funding from The Research Council of Norway, creates national research test sites facility for geotechnical research. Five national test sites are located in Norway and on Svalbard. The research consortium consists of NGI, NTNU, SINTEF/UNIS and NPRA (Norwegian Public Roads Administration). The research project will develop the five sites as field laboratories for the testing and verification of innovative soil investigation and testing methods, and foundation solutions. These sites cover the soil conditions of soft clay, quick clay, silt, sand and permafrost.

This report covers the field work on the Permafrost site performed by SINTEF during the time period March-April 2017 at the Adventdalen site, located in the Longyearbyen area at the old airport/Aurora research station.

2 Background

The field work performed on Svalbard is covered by the subcontract signed by UNIS and SINTEF. The work comprises:

i) Site supervision
ii) Drilling and sampling
iii) Installation of field instrumentation

Responsible for site supervision: Anatoly Sinitsyn

Drilling and sampling crew: Trond Larsen and Kjartan Følke

Installation of casings: Trond Larsen and Kjartan Følke

3 Field location

The national test site for permafrost is located in the Svalbard Archipelago in the surroundings of Longyearbyen (see *Figure 1*). Four proposed sites comprise the NGTS Permafrost site. An overview of the proposed sites for NGTS Permafrost site is presented in Figure 2, these sites are:

- *Adventdalen (1)*
- *Endalen (2)*
- *UNIS East (3)*
- *Longyearbyen Slope (4)*

This report covers field works on the Adventdalen site in March-April 2017. Detailed map of borehole locations is presented in Figure 3.

Figure 1 Overview map of the Svalbard Archipelago.

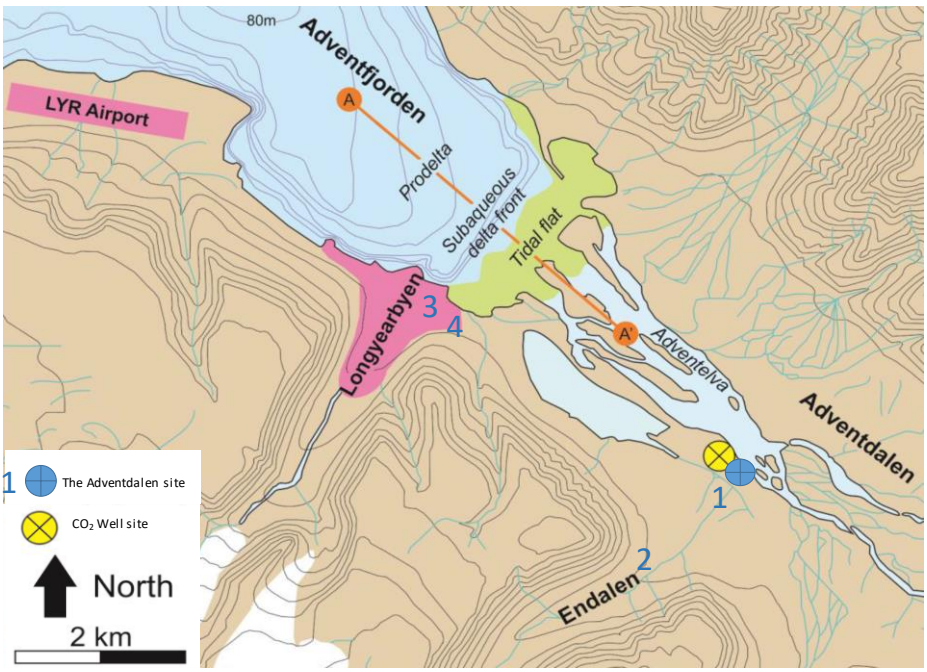


Figure 2 Overview of the Longyearbyen area and proposed sites for NGTS Permafrost site (after / 1/ and / 2/).

Figure 3 Detailed map of borehole locations at the NGTS site in Adventdalen.

Specification of the field work:

- Sampling from active layer:
  - Collection of bag samples with normal auger drilling.
- Sampling of permafrost:
  - Debris form total sounding was collected in plastic bags.
  - SINTEF-modified CRREL coring auger (45mm core diameter).
  - Sampling with 54 mm piston sampler and steel cylinders.
  - Sampling with auger was performed below thick cryopegs and in other challenging ground conditions.
- Installation of casing in boreholes for installation of thermistor strings: the boreholes made after total sounding, coring or augering were used for this purpose.

No sampling was performed from the bedrock. Samples was delivered in cold storage facility at UNIS.

4 Methods and equipment

4.1 Drilling rig

Field work is performed with SINTEFs custom built Geotech 504. The drilling rig can be disassembled to make it easy to transport in parts with helicopter if necessary. The drilling rig is equipped for different types of drilling and sounding, cone penetration testing (CPTU), permafrost coring and conventional piston sampling. The drilling rig in operation in Adventdalen is shown in Figure 4.

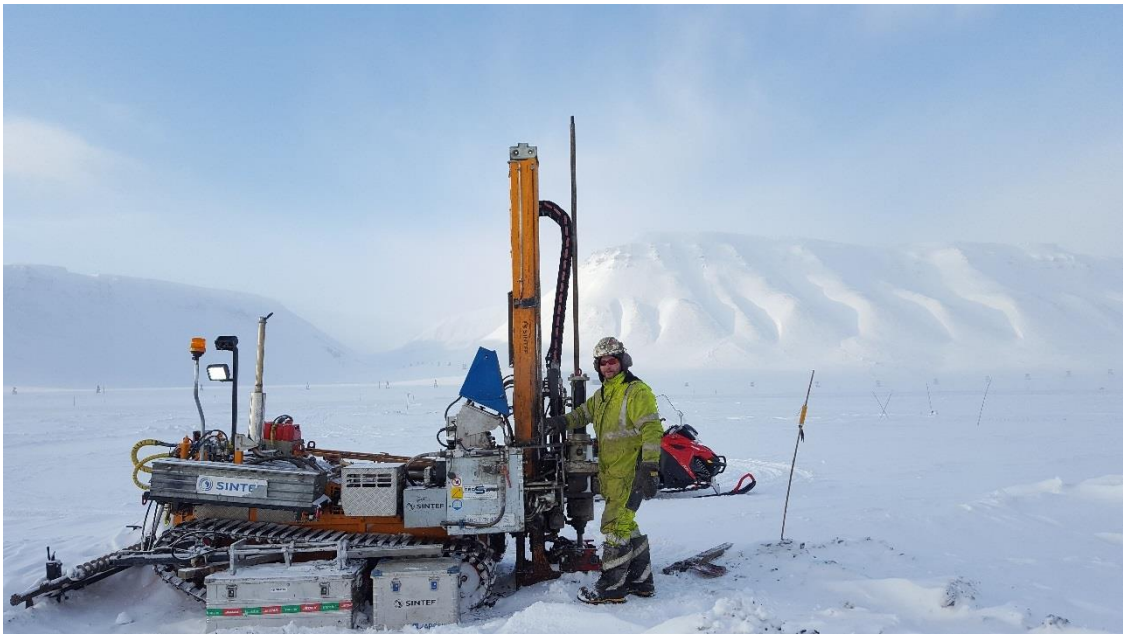


Figure 4 The SINTEF drilling rig in operation in Adventdalen.

4.2 Total sounding

The standard method for total soundings, as specified in the Bulletin no.9 from the Norwegian Geotechnical Society and by the Norwegian Road Authorities (NPRA 2014), is performed by rotating a drill bit into the ground at constant rotation and speed of penetration while recording the soil resistance. Increased rotation speed, flushing and drill hammer is used to penetrate hard layers or rocks. In frozen soils, the resistance is too high to facilitate the required penetration rate, i.e. increased rotation is used at all time and valuable information is lost. Based on this, a modification to the total sounding procedure has been developed by SINTEF / 3/ which allows for obtaining detailed information of the soil profile while maintaining the effectiveness of sounding. The modified total sounding is performed with constant force while logging the penetration rate. Hammering and flushing (in permafrost with air) is performed continuously. The method with modified total sounding has also been used and discussed in / 4/.

Total sounding is applied to perform a quick check in permafrost if there is concern of unfrozen zones or cryopegs, mainly because of high salinity in the ground. A cryopeg is a layer of unfrozen ground that is perennially cryotic (forming part of the permafrost), in which freezing is prevented by freezing-point depression due to the dissolved-solids content of the pore water / 5/.

4.3 Permafrost coring

The SINTEF-modified CRREL coring auger for permafrost in presented in Figure 5. The corer consists of a cutting bit attached to a thick walled hollow core collecting auger. This type of corer has proven to be efficient in collecting cores in fine grained frozen soils. The inner diameter of the corer is 45mm. The corer cut samples of 40 cm length.

The SINTEF permafrost corer ensures penetration in most materials due to the use of poly-crystalline diamond composite (PCD) bit inserts. These inserts are very durable and can even cut cores in rock. This coring barrel is used without drilling fluids. This is a big advantage when operating in cold climate where environmentally unfriendly additives have to be used in order to prevent the liquids from freezing.

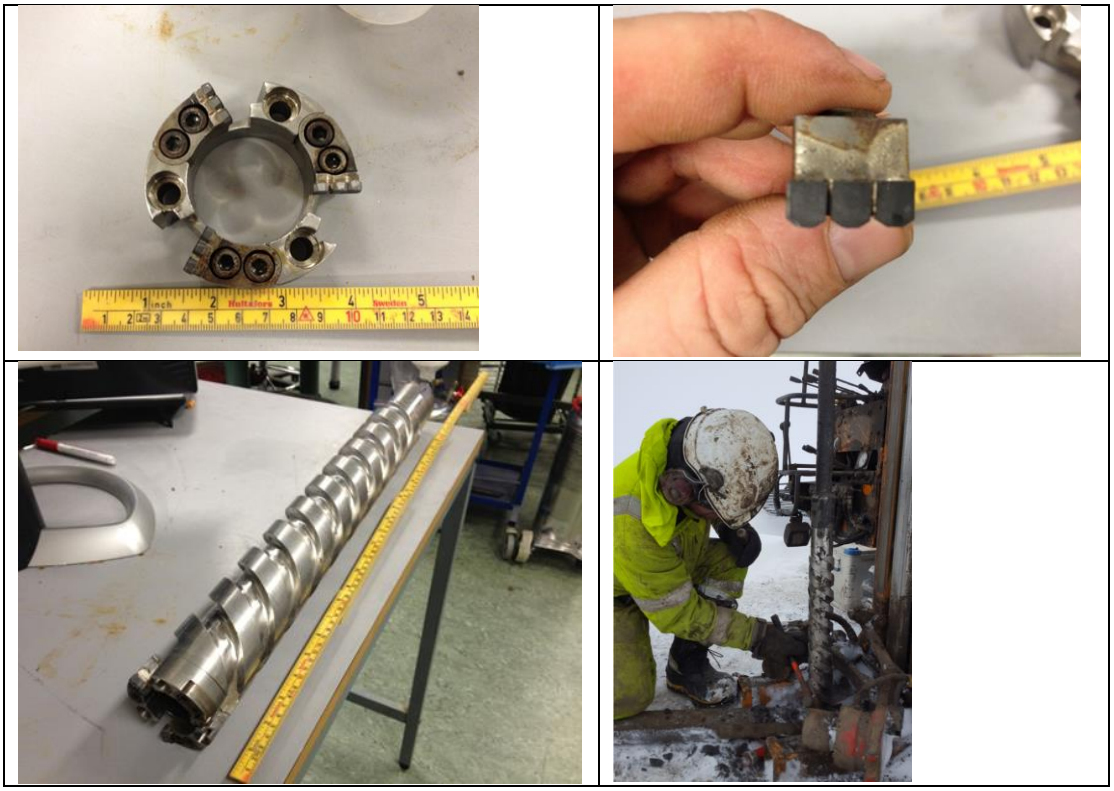


Figure 5 The SINTEF permafrost corer; drill piece (top left), PCD inserts (top right), frost corer assembled (lower left) and sampling in Adventdalen (bottom right).

4.4 Piston sampling

In unfrozen fine-grade soils piston sampling is used to obtain undisturbed samples of soil. SINTEF use the Geonor thin wall, stationary 54 mm piston sampler with cylinders

of steel. Typical length of samples is 0,8 m. The piston sampling has been performed in unfrozen zones, typically at 12-17 m below terrain in Advendtdalen.

4.5 Sampling of fluid

In the boreholes A3-A5 fluid was sampled from unfrozen zones. Typically, these depths were about 14-15m. The salinity of fluid was measured to 7 % NaCl (measured with salinity refractometer). These measurements show that cryopegs are present in Adventdalen.

Table 1 Salinity measured in laboratory on samples from cryopeg zones.

Borehole	Depth of sampling (m)	Salinity, % NaCl	Remarks
A3	14,5-15,3	7,1	Liqide collected from the top of 54-mm sampler.
A3		7,5	Taken from the cryopeg zone.
A3	15,5-16,3	7,0	
A4		7,0	Taken from the cryopeg zone.
A4	14,0-14,8	9,0	Mass of sample is ca 10 g, some evaporation might have taken place, use result with care.
A5		7,0	Taken from the cryopeg zone.

5 Event log

The event log is presented in Table 1.

Table 2 Event log.

Day	Date	Activity
Wednesday	2017-03-01	Travel to Svalbard.
Thursday	2017-03-02	Project meeting. Preparation and checking equipment for field work.
Friday	2017-03-02	Office work.
Monday	2017-03-06	Location of the drilling rig on the site, check A1-A3 with metal detector.
Tuesday	2017-03-07	Total sounding at A1, collection of bag samples.
Wednesday	2017-03-08	Total sounding at A2, collection of bag samples.
Thursday	2017-03-09	Total sounding at A2, collection of bag samples.
Friday	2017-03-10	Total sounding at A3, collection of bag samples.
Monday	2017-03-13	Total sounding at A3 and A2, collection of bag samples.
Tuesday	2017-03-14	Preparations for coring.
Wednesday	2017-03-15	Coring at A3.
Thursday	2017-03-16	Coring at A3.
Friday	2017-03-17	Office work.

Saturday	2017-03-18	Field work was stopped due to very low air temperatures. Drilling rig did not start.
Monday	2017-03-20	Coring at A3.
Tuesday	2017-03-21	Coring at A3.
Wednesday	2017-03-22	Preparations for 54mm sampling at A3.
Thursday	2017-03-23	Sampling with 54 mm sampler in unfrozen zone of A3.
Friday	2017-03-24	Augering A3 to the depth 30 m after sampling with 54 mm sampler was stopped.
Saturday	2017-03-25	Cleaning (augering) and installation of casing at A3. Casing installed to the depth 23 m.
Sunday	2017-03-26	Cleaning A2 to the depth 30 m, installation of casing down to the depth 22,7 m.
Monday	2017-03-27	Augering and coring at A4.
Tuesday	2017-03-28	Coring at A4.
Wednesday	2017-03-29	Coring at A4.
Thursday	2017-03-30	Coring at A4.
Friday	2017-03-31	Cleaning bore hole A4: 0–14 m, 54 mm sampling from 14 to 17 m. Not much water was observed.
Saturday	2017-04-01	Augering at A4. Installation of casing down to 19.5 m: bore hole was filled up with water up to the ground surface after the casing was installed. Bore hole collapsed due to water flowing into it from 14–17 m depth, hence casing was installed at shallower (19.5 m) then initially planned depth (30 m).
Sunday	2017-04-02	Augering (0 - ca 0.5 m) and coring (ca 0.5–4 m) at A5.
Monday	2017-04-03	Coring at A5.
Tuesday	2017-04-04	Coring and augering at A5.
Wednesday	2017-04-05	Traveling from Svalbard.
Tuesday	2017-04-18	Traveling to Svalbard. Stop for one day in Tromsø due to bad weather.
Wednesday	2017-04-19	Arrival in Svalbard.
Thursday	2017-04-20	Meeting with WP-leader. Continued coring and 54mm sampling at A5.
Friday	2017-04-21	Augering and installation of casing in A5.
Saturday	2017-04-22	Maintenance of drilling rig.
Monday	2017-04-24	Cleaning and packing of drilling rig and equipment.
Tuesday	2017-04-25	Travel from Svalbard.

Note: A1–A5 – borehole locations.

6 Weather conditions

The field work was performed in air temperatures down to -20 ºC and with windchill effect the temperatures were down to -30 ºC during fieldwork as seen in *Figure 6*.

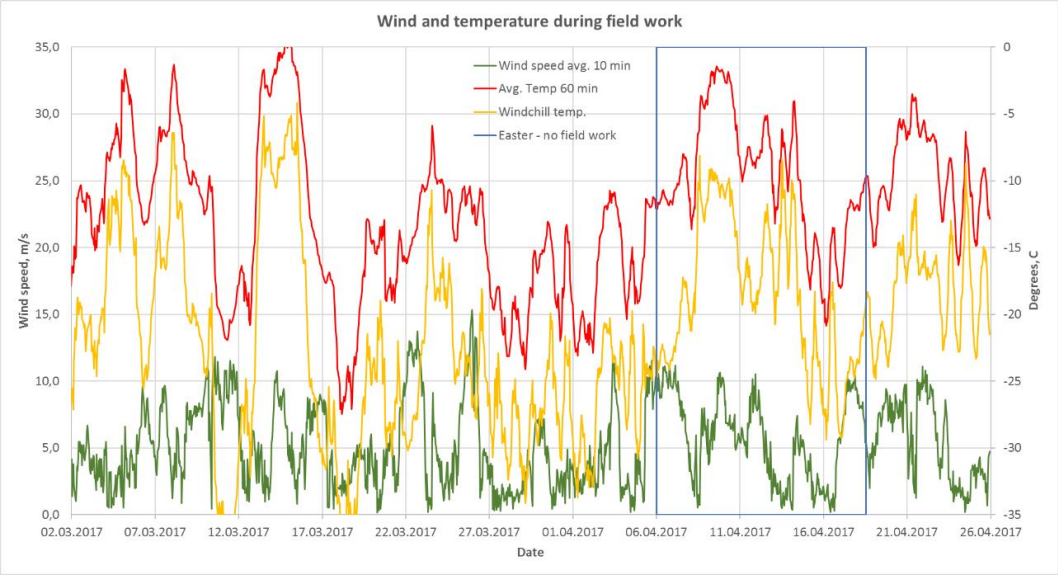


Figure 6 Overview of temperature and wind during the field campaign.

7 Coordinates

The coordinates for the geotechnical boreholes in Adventdalen site are shown in Table 3. Geodetic measurements have been performed with DGPS.

Table 3 Location of geotechnical boreholes in the Adventdalen site.

Place	Borehole	Easting	Northing	Elevation surface, NN2000
Adventdalen site	A1	519020	8680930	4,0
Adventdalen site	A2	519061	8680962	4,0
Adventdalen site	A3	519094	8680997	4,0
Adventdalen site	A4	519149	8680830	4,0
Adventdalen site	A5	519221	8680883	4,0

8 Total sounding

In the field campaign in Adventdalen site in spring 2017 totally 3 holes with total sounding have been performed. The depths of total soundings are shown in Table 4.

Table 4 Total soundings in Advendtdalen site.

Place	Borehole	Sounding depth (m)	File name
Adventdalen	A1	24,6	NGTS AdventdalenA1 20170306 1845
Adventdalen	A2	25,4	NGTS AdventdalenA2 20170308 1849
Adventdalen	A3	26,0	NGTS AdventdalenA3 20170310 1851

The total soundings were supposed to be drilled down to 30 m depth. However, the total soundings were stopped at 25-26 m depth due to weight of drillstring and fear of adfreeze that could lead to loss of the drillstring. None of the total soundings reached the rock surface.

Cryopegs were discovered during total sounding and drilling in all boreholes, typically at 13-16m depth. Potential presence of cryopegs was not excluded at the preparatory stage of field works, it was however not expected to encounter this permafrost feature in the field.

The importance of total sounding in permafrost areas is to distinguish between soil layering, identification of unfrozen zones and detection of rock surface. The result from total sounding is also used to prepare for different sampling techniques. The motivation to continue using total sounding in Advendtdalen after discovery of a cryopeg zone was to look for nearby boreholes with no cryopegs.

The plots of total sounding from holes A1-A3 are shown in Appendix A.

9 Sampling

Cryopegs were encountered at ca 13-16m depth in all drilling locations. Presence of cryopegs caused certain effect on sampling rates. Samples were collected with auger, from cuttings when performing total sounding, with permafrost corer or 54 mm conventional coring with steel cylinders. All samples were properly named, packed (wrapped on plastic and packed in plastic bags) and brought to cold storage at UNIS. Each core sample was marked with borehole number, core number and depth (e.g. A3 prøve 13 5,8-6,2 m). The bag samples from total soundings are taken from the cuttings that flow up from the borehole during total sounding, and were collected on a shuffle. The samples from total sounding is supposed to coincide from the depths close to the drilling bit, since all material is transported with compressed air during the drilling (compressed air blows all the material from the tip up to the surface). Details regarding samples from the different boreholes are shown in Table 5−Table 9. Totally 85 samples of very good quality were taken using the permafrost corer, and pictures of these samples are shown in Appendix A. Totally 6 samples were taken from unfrozen zones with 54mm sampler, and 25 samples from auger and 28 samples of cuttings from total soundings were put in plastic bags.

Table 5 Samples collected in borehole A1.

Depth top	Depth bottom	Sampling method	Sample wrap	Picture
0,0	0,5	Auger	Bag	No
0,5	1.0	Auger	Bag	No
1,0	1,5	Cuttings from total sounding	Bag	No
2,0	3,0	Cuttings from total sounding	Bag	No
3,0	4,0	Cuttings from total sounding	Bag	No
5,0	7,0	Cuttings from total sounding	Bag	No
Ca 10,0		Cuttings from total sounding	Bag	No

Table 6 Samples collected in borehole A2.

Depth top	Depth bottom	Sampling method	Sample wrap	Picture
0,0	0,5	Auger	Bag	No
0,5	1.0	Auger	Bag	No
1,0	2,0	Cuttings from total sounding	Bag	No
2,0	3,0	Cuttings from total sounding	Bag	No
3,0	4,0	Cuttings from total sounding	Bag	No
4,0	5,0	Cuttings from total sounding	Bag	No
5,0	6,0	Cuttings from total sounding	Bag	No
6,0	7,0	Cuttings from total sounding	Bag	No
7,0	8,0	Cuttings from total sounding	Bag	No
8,0	9,0	Cuttings from total sounding	Bag	No
9,0	10,0	Cuttings from total sounding	Bag	No
12,0	14,0	Cuttings from total sounding	Bag	No
26,0	27,0	Auger	Bag	No

Table 7 Samples collected in borehole A3.

Depth top	Depth bottom	Sampling method	Sample name	Sample wrap	Picture
0,0	0,4	Auger		Bag	No
0,4	1.0	Cuttings from total sounding		Bag	No
1,0	2,0	Cuttings from total sounding		Bag	No
2,0	3,2	Cuttings from total sounding		Bag	No
3,2	4,0	Cuttings from total sounding		Bag	No
4,0	5,0	Cuttings from total sounding		Bag	No
5,0	6,0	Cuttings from total sounding		Bag	No
6,0	7,0	Cuttings from total sounding		Bag	No
7,0	8,0	Cuttings from total sounding		Bag	No
8,0	9,0	Cuttings from total sounding		Bag	No
9,0	10,0	Collected from total sounding		Bag	No
10,0	11,0	Cuttings from total sounding		Bag	No
11,0	12,0	Cuttings from total sounding		Bag	No
20,0	30,0	Cuttings from total sounding		Bag	No
0,8	1,2	Permafrost corer	Pr.1	Bag	Yes
1,3	1,7	Permafrost corer	Pr.2	Bag	Yes
1,8	2,2	Permafrost corer	Pr.3	Bag	Yes
2,2	2,7	Permafrost corer	Pr.4	Bag	Yes
2,7	3,0	Permafrost corer	Pr.5	Bag	Yes
3,0	3,4	Permafrost corer	Pr.6	Bag	Yes
3,4	3,8	Permafrost corer	Pr.7	Bag	Yes
3,8	4,2	Permafrost corer	Pr.8	Bag	Yes
4,2	4,6	Permafrost corer	Pr.9	Bag	Yes
4,6	5,0	Permafrost corer	Pr.10	Bag	Yes
5,0	5,4	Permafrost corer	Pr.11	Bag	Yes
5,4	5,8	Permafrost corer	Pr.12	Bag	Yes
5,8	6,2	Permafrost corer	Pr.13	Bag	Yes
6,2	6,6	Permafrost corer	Pr.14	Bag	Yes

6,6	7,0	Permafrost corer	Pr.15	Bag	Yes
7,0	7,4	Permafrost corer	Pr.16	Bag	Yes
7,4	7,8	Permafrost corer	Pr.17	Bag	Yes
7,8	8,2	Permafrost corer	Pr.18	Bag	Yes
8,2	8,6	Permafrost corer	Pr.19	Bag	Yes
8,6	9,0	Permafrost corer	Pr.20	Bag	Yes
9,0	9,4	Permafrost corer	Pr.21	Bag	Yes
9,3	9,7	Permafrost corer	Pr.22	Bag	Yes
9,7	10,1	Permafrost corer	Pr.23	Bag	Yes
10,1	10,5	Permafrost corer	Pr.24	Bag	Yes
10,5	10,9	Permafrost corer	Pr.25	Bag	Yes
10,9	11,3	Permafrost corer	Pr.26	Bag	Yes
11,3	11,7	Permafrost corer	Pr.27	Bag	Yes
11,7	12,1	Permafrost corer	Pr.28	Bag	Yes
12,1	12,5	Permafrost corer	Pr.29	Bag	Yes
12,5	12,9	Permafrost corer	Pr.30	Bag	Yes
12,9	13,3	Permafrost corer	Pr.31	Bag	Yes
13,3	13,7	Permafrost corer	Pr.32	Bag	No
13,7	14,1	Permafrost corer	Pr.33	Bag	Yes
14,5	15,3	54 mm sampler	Prøve 1	Steel cylinder	No
15,5	16,3	54 mm sampler	Prøve 2	Steel cylinder	No
16,3	16,8	54 mm sampler	Prøve 3	Steel cylinder	No
18,0	19,0	Auger		Bag	No
21,0	22,0	Auger		Bag	No
23,0	24,0	Auger		Bag	No
25,0	26,0	Auger		Bag	No
27,0	28,0	Auger		Bag	No
29,0	30,0	Auger		Bag	No

Table 8 Samples collected in borehole A4.

Depth top	Depth bottom	Sampling method	Sample name	Sample wrap	Picture
0,0	1,0	Auger		Bag	No
1,0	1,3	Auger		Bag	No
1,3	1,7	Permafrost corer	Pr.1	Bag	Yes
1,7	2,1	Permafrost corer	Pr.2	Bag	Yes
2,1	2,5	Permafrost corer	Pr.3	Bag	Yes
2,5	2,9	Permafrost corer	Pr.4	Bag	Yes
2,9	3,3	Permafrost corer	Pr.5	Bag	Yes
3,3	3,7	Permafrost corer	Pr.6	Bag	Yes
3,7	4,1	Permafrost corer	Pr.7	Bag	Yes
4,1	4,5	Permafrost corer	Pr.8	Bag (not frozen)	Yes
4,5	4,9	Permafrost corer	Pr.9	Bag (not frozen)	Yes
4,9	5,3	Permafrost corer	Pr.10	Bag	Yes
5,3	5,7	Permafrost corer	Pr.11	Bag	Yes
5,7	6,1	Permafrost corer	Pr.12	Bag	Yes
6,1	6,5	Permafrost corer	Pr.13	Bag	Yes

6,5	6,9	Permafrost corer	Pr.14	Bag	Yes
6,9	7,3	Permafrost corer	Pr.15	Bag	Yes
7,3	7,7	Permafrost corer	Pr.16	Bag	Yes
7,7	8,1	Permafrost corer	Pr.17	Bag	Yes
8,1	8,5	Permafrost corer	Pr.18	Bag	Yes
8,5	8,9	Permafrost corer	Pr.19	Bag	Yes
8,9	9,3	Permafrost corer	Pr.20	Bag	Yes
9,3	9,7	Permafrost corer	Pr.21	Bag	Yes
9,7	10,1	Permafrost corer	Pr.22	Bag	Yes
10,5	10,9	Permafrost corer	Pr.23	Bag	Yes
10,9	11,3	Permafrost corer	Pr.24	Bag	Yes
11,3	11,7	Permafrost corer	Pr.25	Bag	Yes
11,7	12,1	Permafrost corer	Pr.26	Bag	Yes
12,1	12,5	Permafrost corer	Pr.27	Bag	Yes
12,5	12,9	Permafrost corer	Pr.28	Bag	Yes
12,9	13,7	No sample		-	-
Ca 14	Ca 15	54 mm sampler		Steel cylinder	No
Ca 15	Ca 16	54 mm sampler		Steel cylinder	No
Ca 16	Ca 17	54 mm sampler		Steel cylinder	No
26,0	27,0	Auger		Bag	No
28,0	29,0	Auger		Bag	No

Table 9 Samples collected in borehole A5.

Depth top	Depth bottom	Sampling method	Sample name	Sample wrap	Picture
0,0	0,5	Auger	Prøve 1	Bag	No
0,5	1,5	Auger	Prøve 2	Bag	No
1,5	1,9	Permafrost corer	Pr.3	Bag	Yes
1,9	2,3	Permafrost corer	Pr.3	Bag	Yes
2,3	2,7	Permafrost corer	Pr.5	Bag	Yes
2,7	3,1	Permafrost corer	Pr.6	Bag	Yes
3,1	3,5	Permafrost corer	Pr.7	Bag	Yes
3,5	3,9	Permafrost corer	Pr.8	Bag	Yes
3,9	4,3	Permafrost corer	Pr.9	Bag	Yes
4,3	4,7	Permafrost corer	Pr.10	Bag	Yes
4,7	5,1	Permafrost corer	Pr.11	Bag	Yes
5,1	5,5	Permafrost corer	Pr.12	Bag	Yes
5,5	5,9	Permafrost corer	Pr.13	Bag	Yes
5,9	6,3	Permafrost corer	Pr.14	Bag	Yes
6,3	6,7	Permafrost corer	Pr.15	Bag	Yes
6,7	7,1	Permafrost corer	Pr.16	Bag	Yes
7,1	7,5	Permafrost corer	Pr.17	Bag	Yes
7,5	7,9	Permafrost corer	Pr.18	Bag	Yes
7,9	8,3	Permafrost corer	Pr.19	Bag	Yes
8,3	8,7	Permafrost corer	Pr.20	Bag	Yes
8,7	9,1	Permafrost corer	Pr.21	Bag	Yes
9,1	9,5	Permafrost corer	Pr.22 (soft)	Bag	Yes

9,5	9,9	Permafrost corer	Pr.23	Bag	Yes
9,9	10,3	Permafrost corer	Pr.24	Bag	Yes
10,3	10,7	No sample obtained	-	-	No
10,7	12,0	Auger		Bag	No
12,2	12,6	Permafrost corer	Pr.24B	Bag	Yes
12,6	13,0	Permafrost corer	Pr.25	Bag	Yes
15,2	16,0	54 mm sampler		Steel cylinder	No
16,0	16,5	54 mm sampler		Steel cylinder	No
19,0	20,0	Auger		Bag	No
21,0	22,0	Auger		Bag	No
23,0	24,0	Auger		Bag	No
25,0	26,0	Auger		Bag	No
26,0	27,0	Auger		Bag	No
27,0	28,0	Auger		Bag	No

10 Installation of casings

In this project thermistors for measuring ground temperature in depth shall be installed in casings. The casings consisted of 2m sections of Ø50mm PEHD (poly ethylene high density) pipes satisfying DS2119 (Danish standard) (/ 6/) and KIWA certified. Tape were used in the threaded coupling between casing sections to avoid water entering the casing. The casings were pushed down in the open holes A2−A5.

It can, in general, be recommended to equip boreholes for thermal measurements in permafrost zones with casing due to the following reasons: i) practical experience shows that casings were used in most of the cases / 7/ for temperature measurements in permafrost zones due to a number of practical reasons; ii) in particular, casings protect the wire of the thermistor string from rupture if frost heave occur at the site (this was not known for the Adventdalen site at the time of installation of casing/thermistor string); iii) casing protects the borehole from collapsing if cryopegs are encountered; iv) casing provides an opportunity to change the thermistor string if some of sensors are malfunctioning during exploitation.

Total sounding had been performed in these holes previously, and the holes were cleaned by auger prior to installation of casings. The installed casing depths in boreholes A2−-A5 are shown in *Table 10*.

Table 10 Casing depths in Adventdalen.

Place	Borehole	Installation depth (m)
Adventdalen site	A2	22,7
Adventdalen site	A3	23,0
Adventdalen site	A4	19,5
Adventdalen site	A5	19,5

Thermistor strings will be installed by UNIS-personnel.

11 General soil description

The active layer at the site in Advendtdalen is supposed to have a thickness of 1 m. This layer was frozen during the field campaign. The sediments above the cryopeg layer seem to consist mainly of silts and sands, which can be visually seen from the samples taken with the permafrost corer. Within the cryopeg layer (13−16m depth) some 54 mm piston samples have been taken. The fact that it was possible to take cores with 54 mm sampler indicates that the material consists of fine-grained material in this layer. From visual inspection of samples silts and sands also seem to dominate below the cryopeg layer down to 22-23m depth. Below this depth the sediments seem to be more fine-grained.

12 Comments to field investigation

The field investigations in Adventdalen were performed during spring with snow cover and low temperatures. This time was selected to prevent damage to the vulnerable tundra. Drilling at this time of the year will increase the amount of time to perform the geotechnical investigations. The fact that cryopegs were encountered lead to some problems, which were time consuming.

Total sounding can, in general, be recommended as a tool for identification of unfrozen zones/cryopegs in permafrost conditions, and for identification of the rock surface. In general, need for identification of unfrozen zones/cryopegs can arise as i) a part of studies on hydrology regime; ii) as a ground truthing for geophysical studies; iii) as a preliminary field investigations for design of sampling campaign; iv) as a tool when one is looking for an area without unfrozen zones/cryopegs.

It would have been useful to perform total sounding prior to field work in spring 2017, i.e. in the autumn 2016. The latter would have given an opportunity to design sampling campaign in spring 2017 by taking into account the detected cryopeg features. This would be especially useful to design sampling routine below the cryopeg layer (at the depths great than ca 13 m). Rates of total sounding and sampling appeared to be within reasonable range.

It would have been useful to perform geophysical investigations/analyze existing geophysical data in Adventdalen prior to the geotechnical investigation campaign. This could reveal the existence of cryopegs prior to the performance of total soundings and sampling. Total sounding performed with the knowledge from geophysical investigations could be a ground truthing method to confirm the existence of cryopegs.

It is suggested to test total sounding at the UNIS East site. This will help to verify the idea that one can distinguish frozen sand (present in Adventdalen site) from frozen clay (present in UNIS East) based on results from the total sounding. The latter may lead to development of a method for mapping permafrost conditions (regarding the soil types).

It can be recommended to install additional thermistor strings in Adventdalen site by using double casing technique which was implemented at the UNIS East. The latter

technique could be considered as suitable for installation of thermistor strings in zones with cryopegs.

Obtained core samples had a very good quality and are, in particular, suitable for mechanical testing. Mechanical testing should be suggested. Values of mechanical parameters obtained from mechanical tests can be more suitable than the ones obtained by index properties if one considers analysis of new foundation solutions on the site in the future.

13 References

/ 1/ Gilbert, G.L., Sedimentology and geocryology of an Arctic fjord head delta (Adventdalen, Svalbard), in Department of Geosciences, Faculty of Mathematics and Natural Sciences. 2014, University of Oslo. p. 133.

/ 2/ Arne Instanes, UNIS, Norwegian GeoTest Sites (Nasjonale geoforsøksfelt), Techical Note 2016-1 Selection of sites, dated September 13, 2016. 8 pages + 4 enclosures.

/ 3/ Finseth, J. and Wold, M., Experiences from geotechnical sampling and sounding in Permafrost. EUCOP 2010, Svalbard, Norway.

/ 4/ Husdal, E., The application of modified total sounding techniques in frozen ground, Trondheim, Master Thesis NTNU, June, 2011

/ 5/ Van Everdingen, R.O., Muli-Language Glossary of Permafrost and Related Ground-Ice Terms. 1998, International Permafrost Association: The Arctic Institute of North America, The University of Calgary, Calgary, Alberta, Canada T2N 1N4.3.

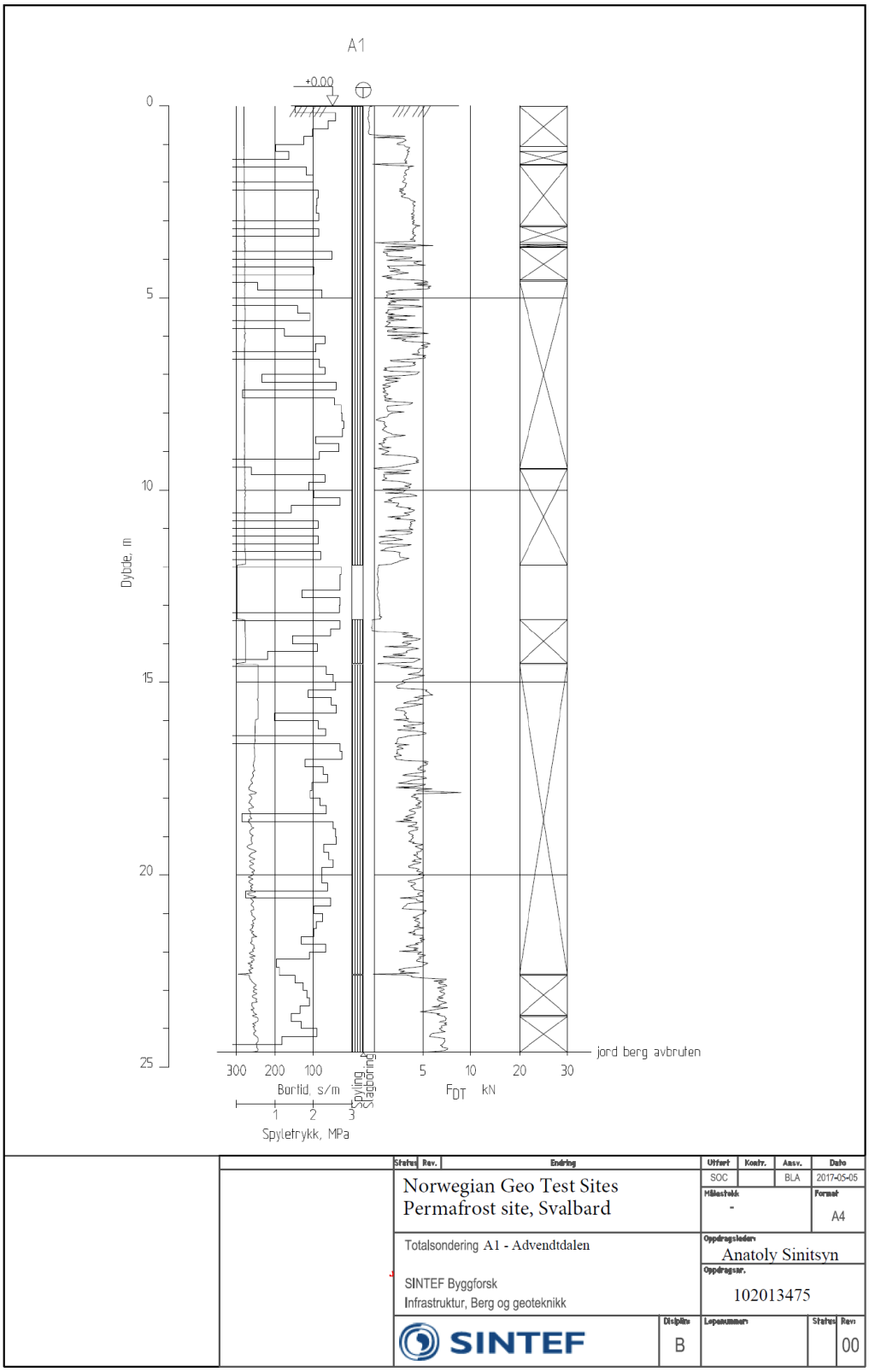
/ 6/ DS 2119 TILLÆG:1989 (withdrawn), Pressure pipes of polyethylene (PEL, PEM and PEH) for water supply. p. 4.

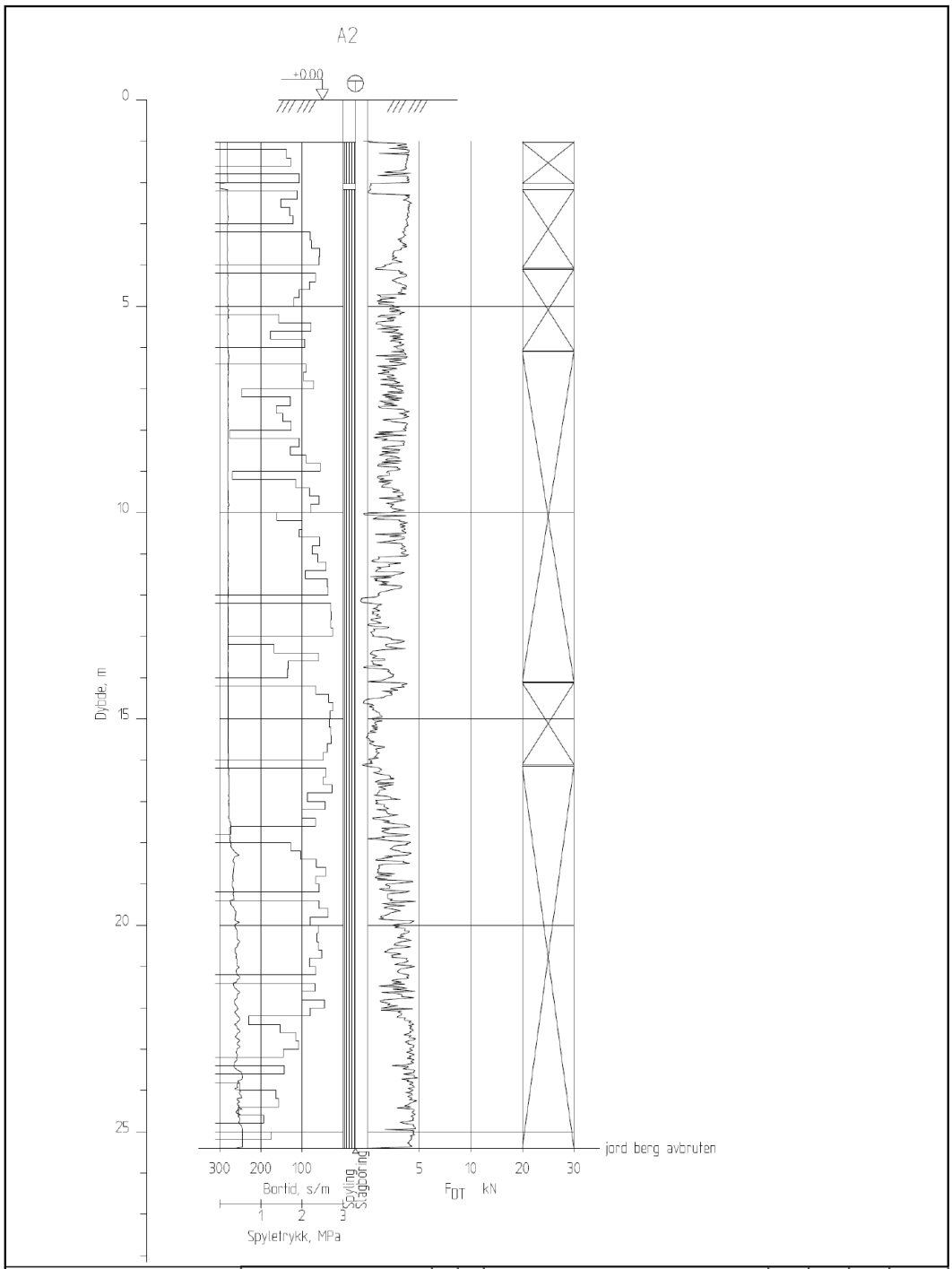
/ 7/ Balmand, E., State of the art: thermal measurement techniques in permafrost. SAMCoT-report SBF 2012 A0134, February 2012.

Appendix A

TOTAL SOUNDINGS

A1 Total sounding results





Status	Rev.	Endring	Utført	Kontr.	Ansv.	Dato
			SOC		BLA	2017-05-05

Norwegian Geo Test Sites
Permafrost site, Svalbard

Totalsondering A2 - Advendtdalen

SINTEF Byggforsk
Infrastruktur, Berg og geoteknikk

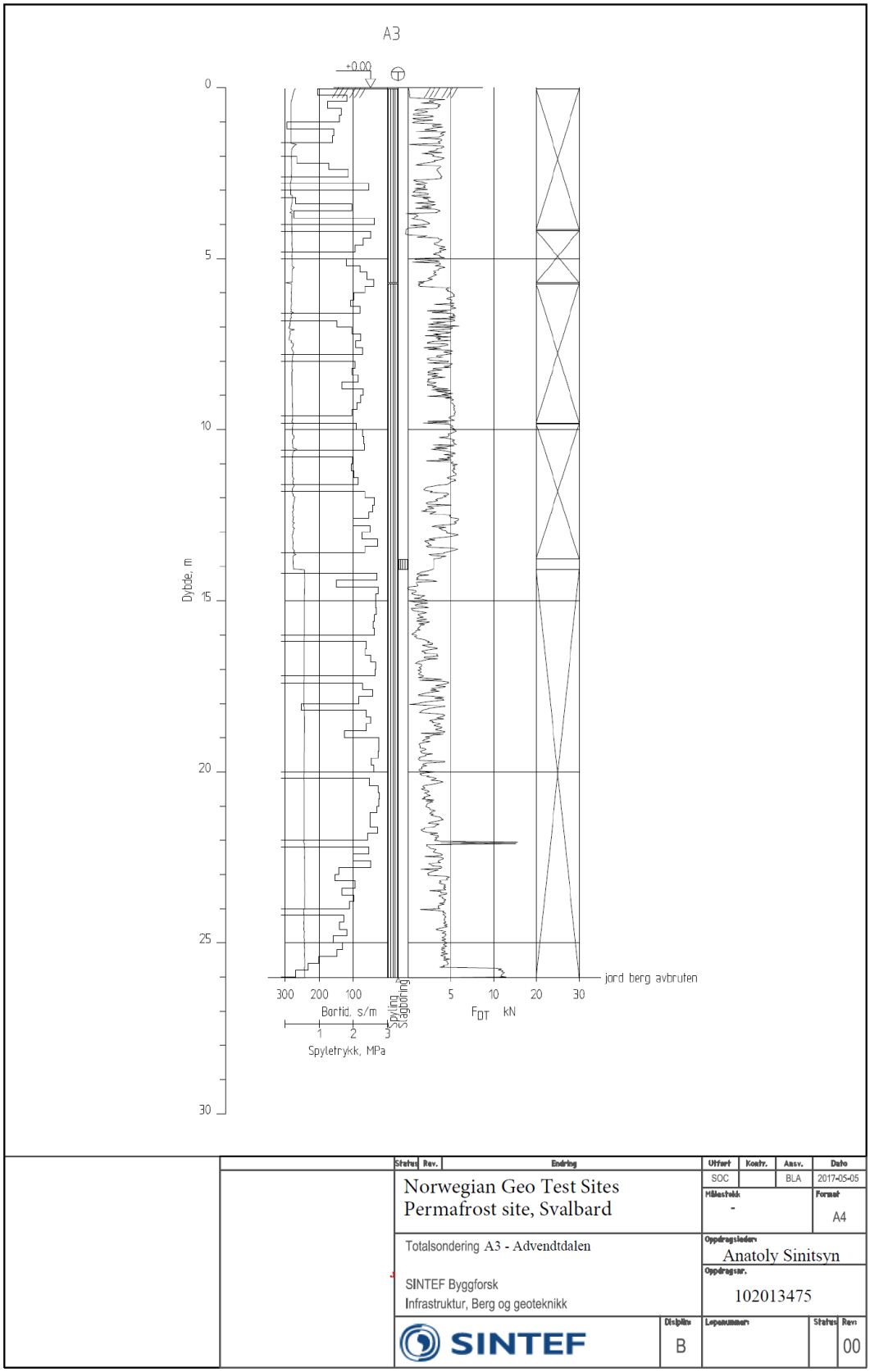
Målestokk	Format
-	A4

Oppdragsleder: Anatoly Sinitsyn

Oppdragsnr.: 102013475

SINTEF

Disiplin	Løpenummer	Status	Rev.
B			00


A3
+0.00
0
5
10
15
20
25
30
Dybde, m
300
200
100
Bortid. s/m
Spyling
Slagboring
1
2
3
Spyletrykk, MPa
5
10
20
30
F_{DT} kN
jord berg avbruten
Norwegian Geo Test Sites
Permafrost site, Svalbard
Totalsondering A3 - Advendtdalen
SINTEF Byggforsk
Infrastruktur, Berg og geoteknikk
SINTEF
Utført
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2017-05-05
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Anatoly Sinitsyn
Oppdragsnr.
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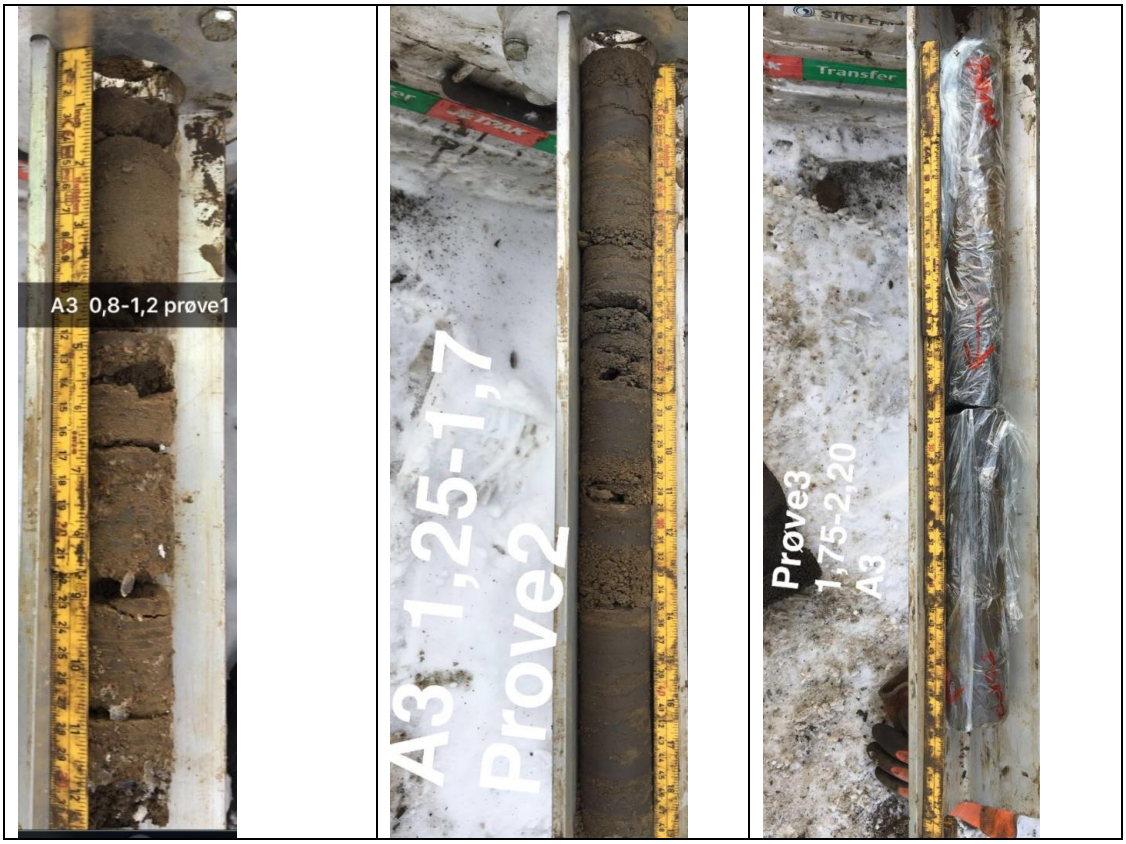
Appendix B

SAMPLE PICTURES

B1 Pictures of core samples – borehole A3



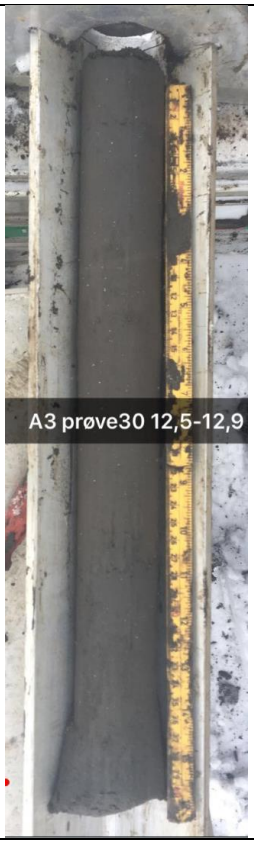

A3 Prøve4 2,2-2,65
Prøve5 2,65-3,0m
Prøve6 3,0-3,4m A3
A3 Prøve7 3,4-3,8m
A3 prøve8 3,8-4,2
A3 prøve9 4,2-4,6m


A3 prøve10 4,6-5,0m
A3 prøve11 5,0-5,4m
A3 prøve12 5,4-5,8m
A3 prøve13 5,8-6,2m
A3 prøve14 6,2 -6,6
A3 prøve15 6,6-7,0m


A3 prøve 16 7,0-7,4
A3 prøve17 7,4-7,8
A3 prøve18 7,8-8,2
A3 prøve19 8,2-8,6
A3 prøve20 8,6-9,0
A3prøve 21 9,0-9,4m


A3prøve22 9,3-9,7m
A3prøve23 9,7-10,1m
A3 prøve24 10,1-10,5m
A3 prøve25 10,5-10,9m
A3 prøve26 10,9-11,3m
A3 prøve27 11,3-11,7m

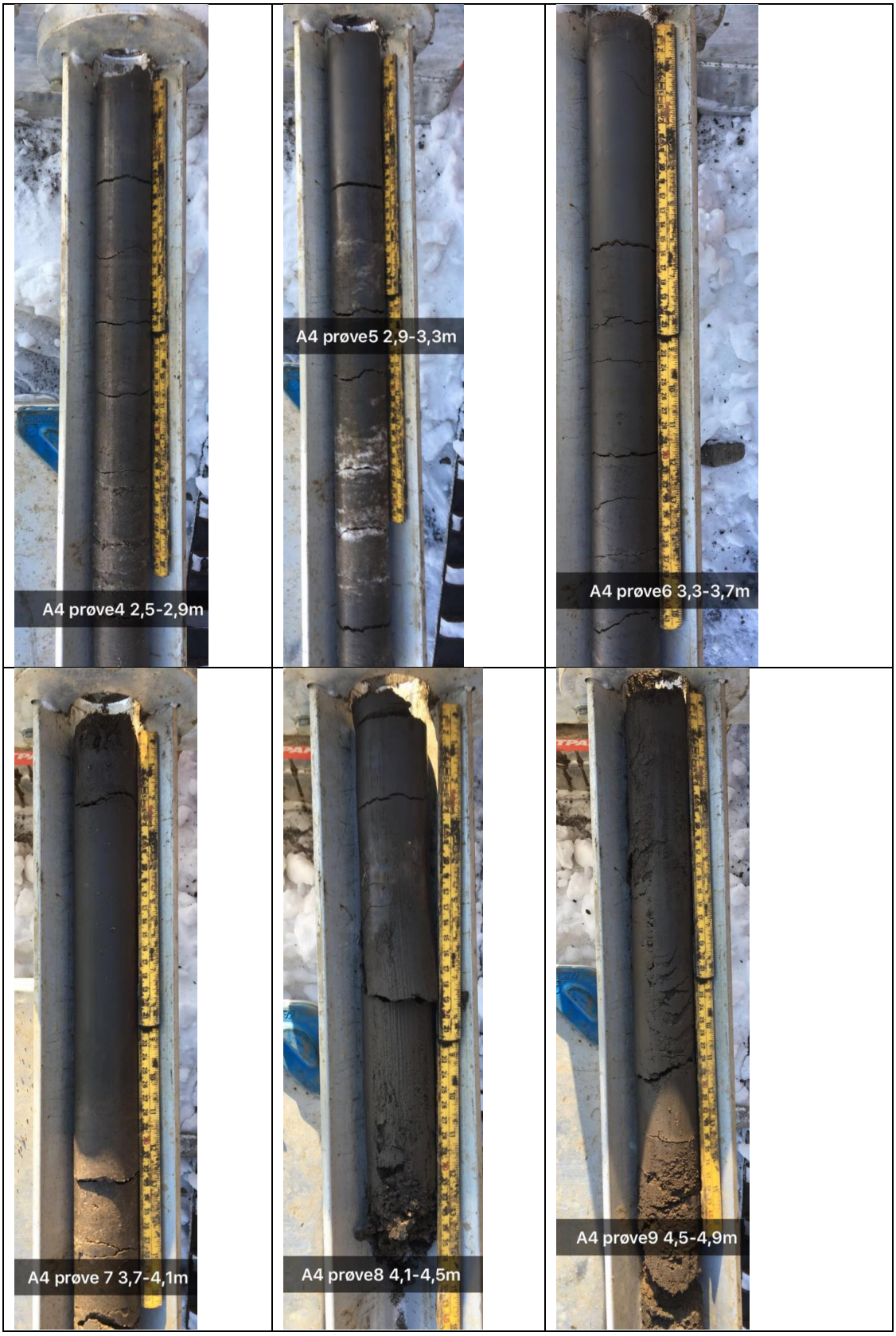

A3 prøve28 11,7-12,1

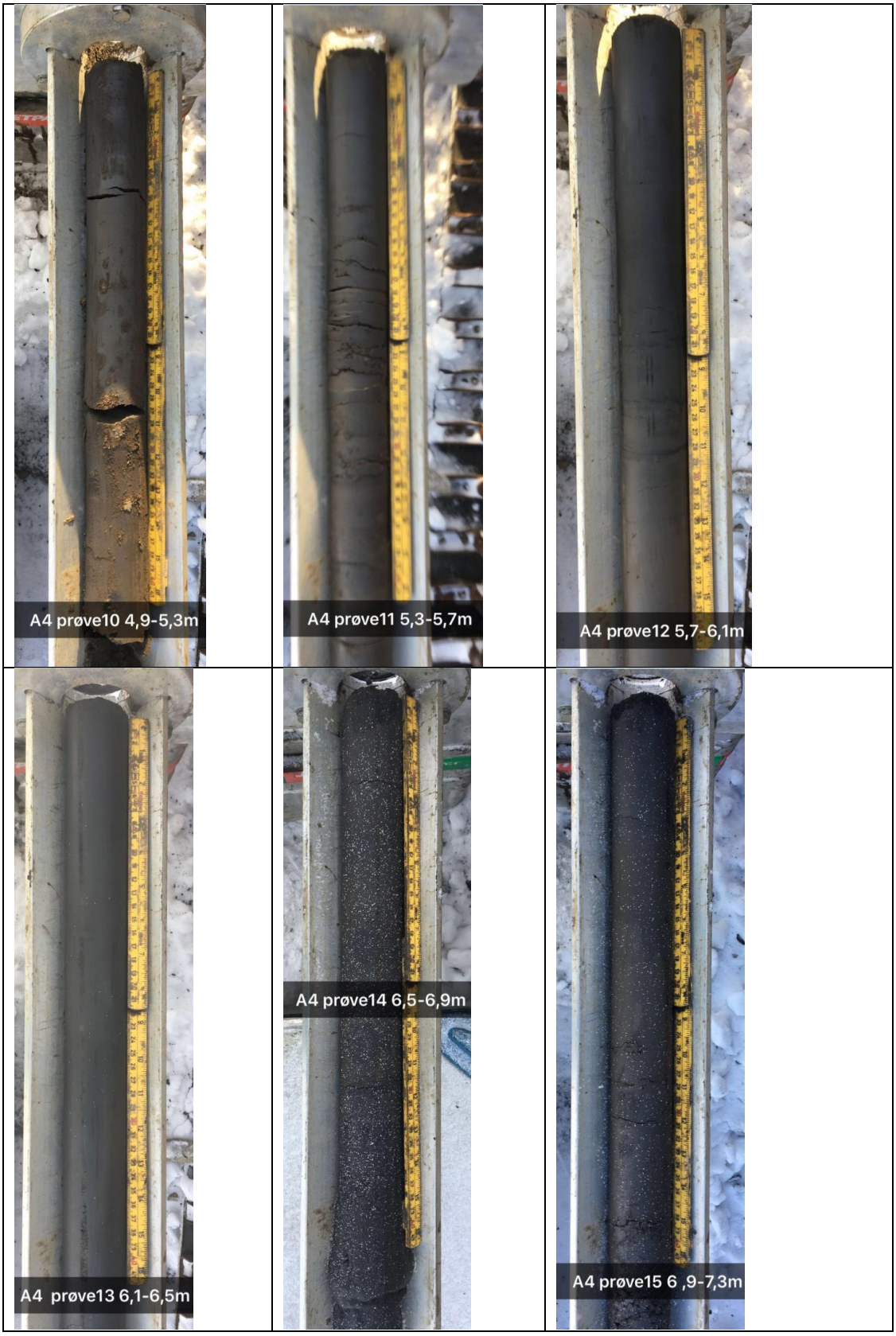

A3 prøve30 12,5-12,9

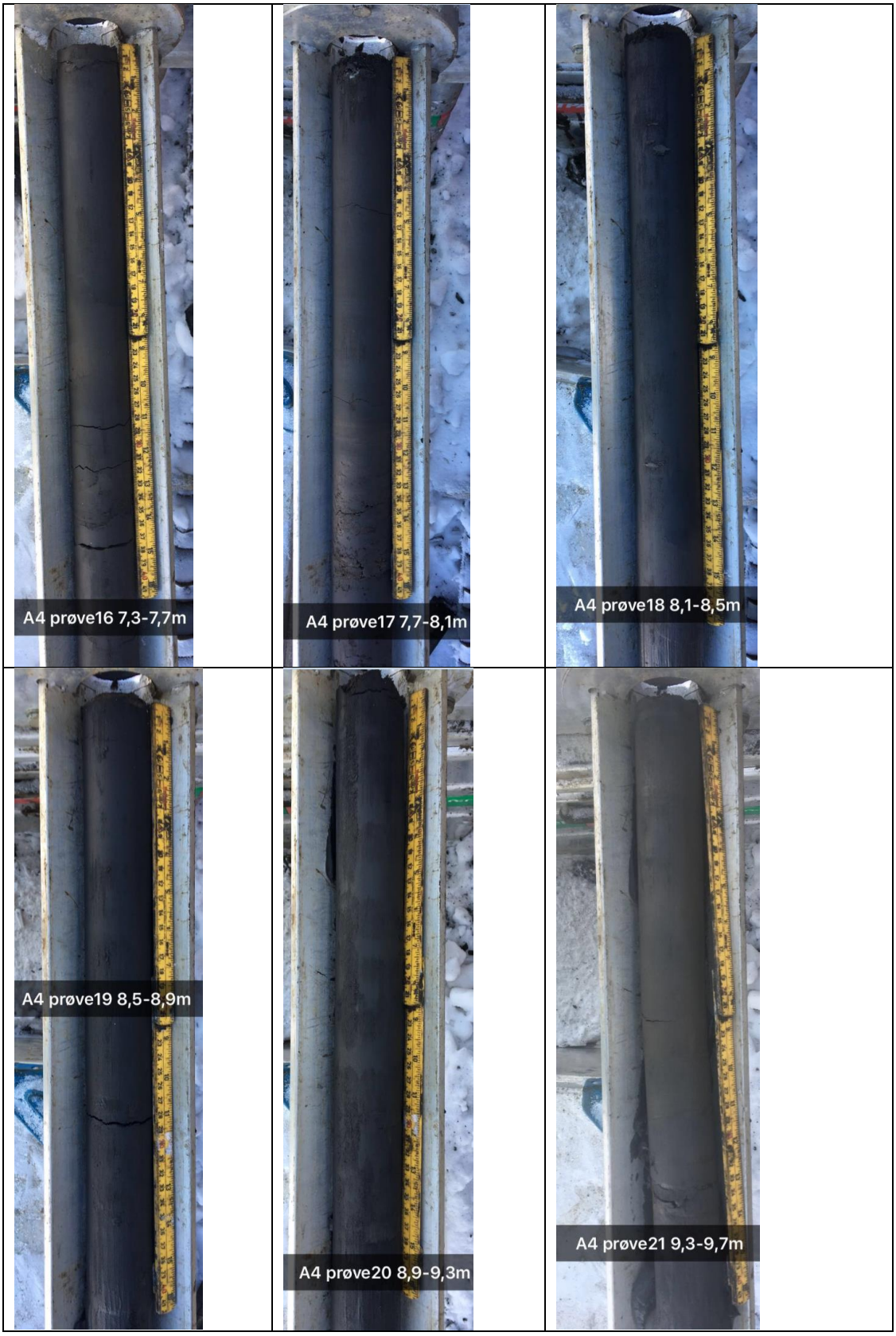

A3 prøve31 12,9-13,3m


A3 prøve33 13,7-14,1m

B2 Pictures of core samples – borehole A4


A4 prøve4 2,5-2,9m
A4 prøve5 2,9-3,3m
A4 prøve6 3,3-3,7m
A4 prøve 7 3,7-4,1m
A4 prøve8 4,1-4,5m
A4 prøve9 4,5-4,9m


A4 prøve10 4,9-5,3m
A4 prøve11 5,3-5,7m
A4 prøve12 5,7-6,1m
A4 prøve13 6,1-6,5m
A4 prøve14 6,5-6,9m
A4 prøve15 6 ,9-7,3m


A4 prøve16 7,3-7,7m
A4 prøve17 7,7-8,1m
A4 prøve18 8,1-8,5m
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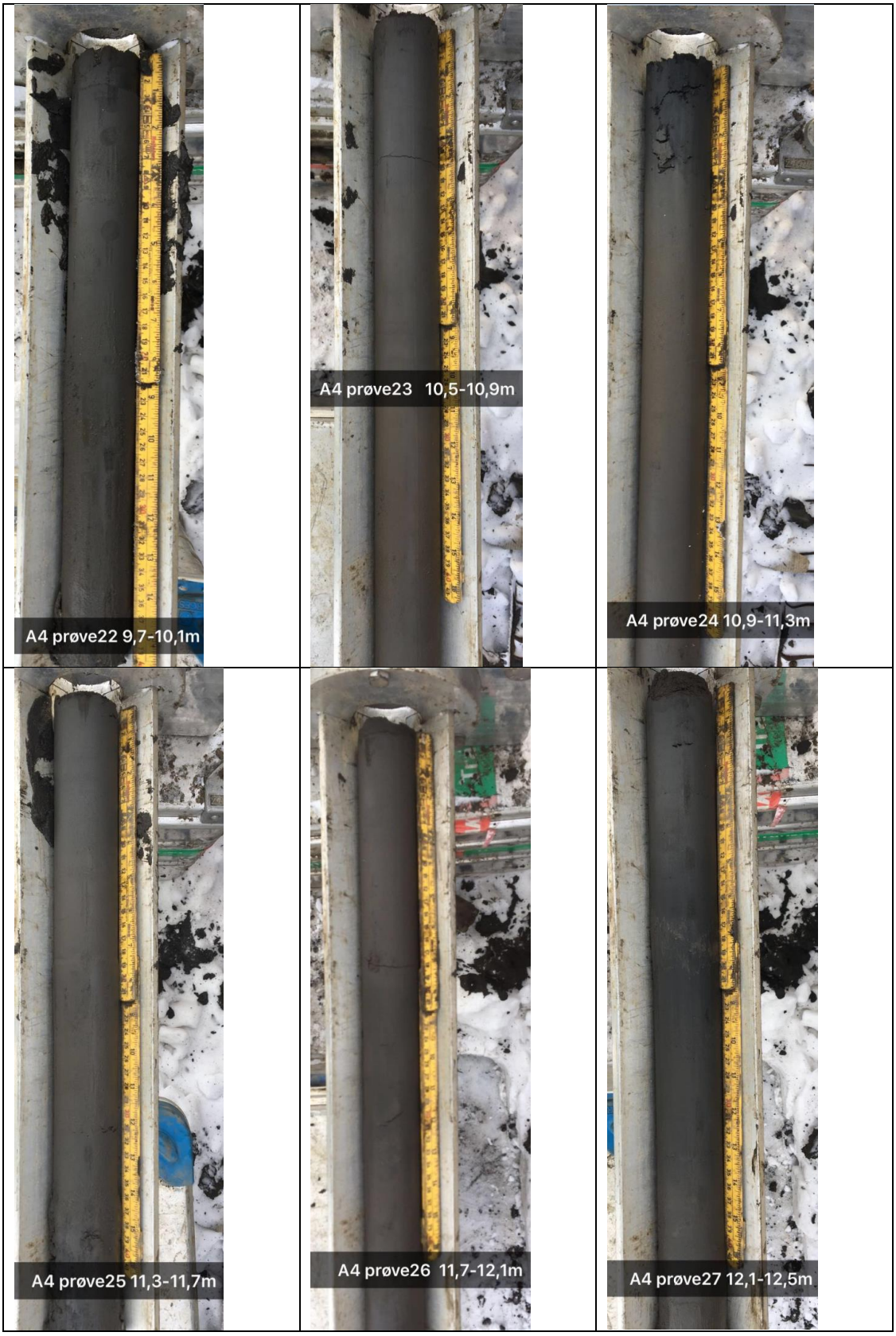
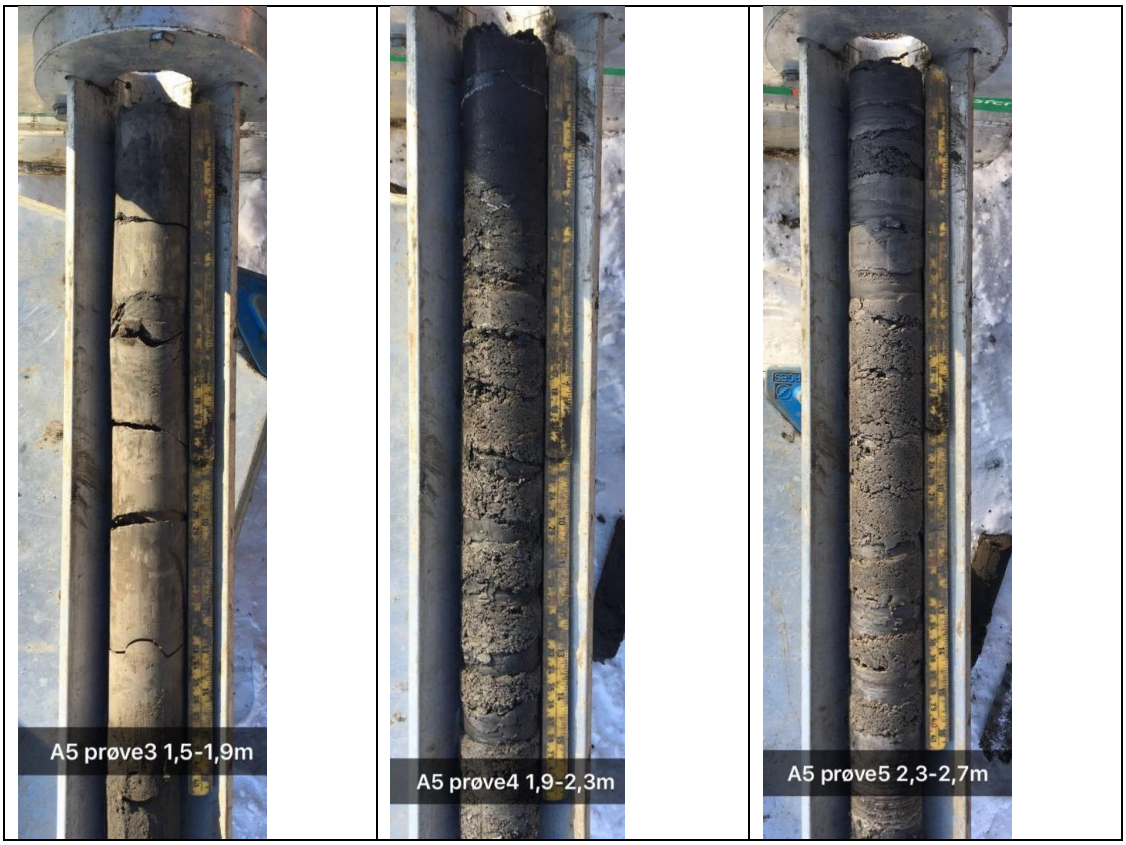
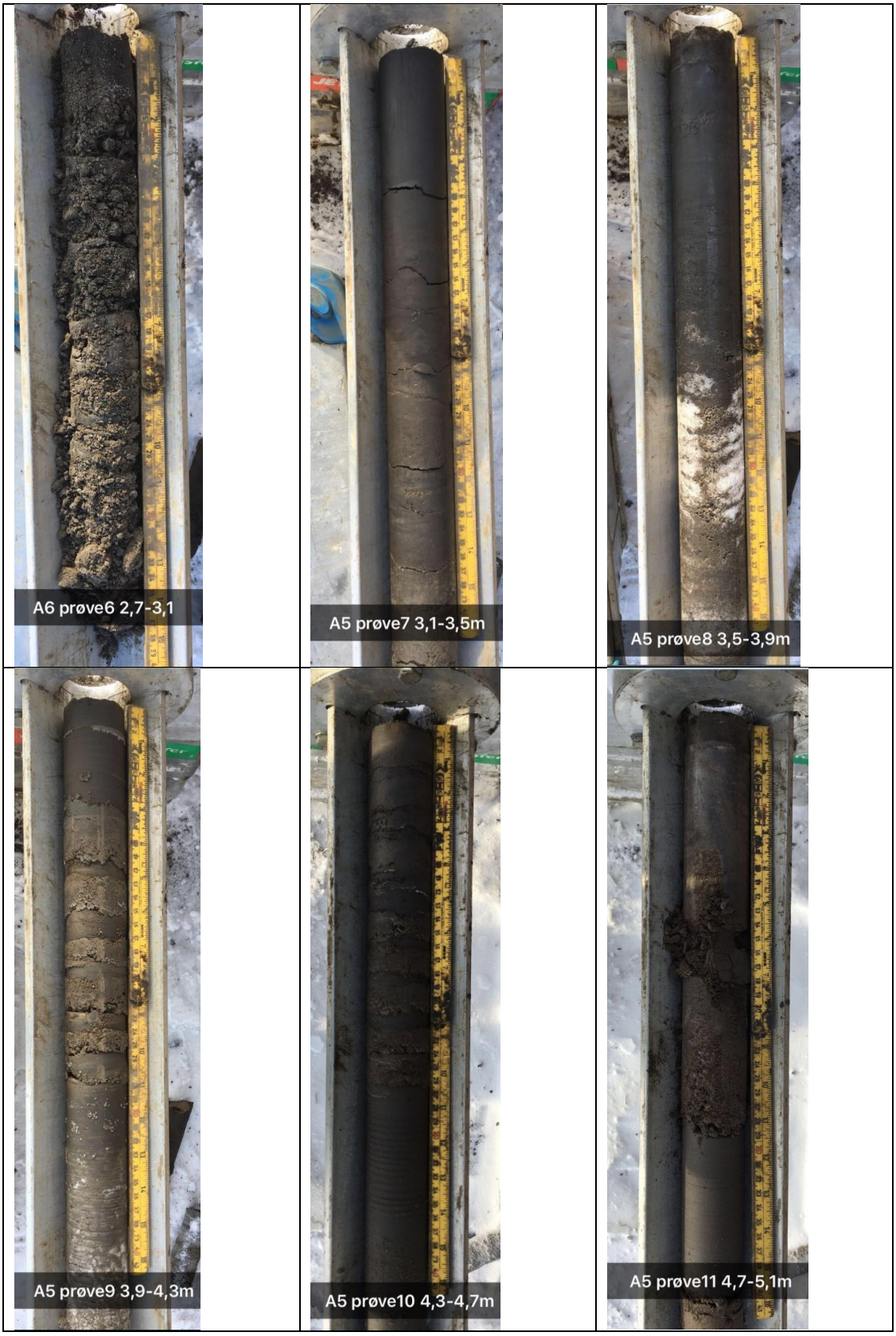
A4 prøve20 8,9-9,3m
A4 prøve21 9,3-9,7m


A4 prøve22 9,7-10,1m
A4 prøve23 10,5-10,9m
A4 prøve24 10,9-11,3m
A4 prøve25 11,3-11,7m
A4 prøve26 11,7-12,1m
A4 prøve27 12,1-12,5m

 A4 prøve28 12,5-12,9m		

B4 Pictures of core samples – borehole A5




A6 prøve6 2,7-3,1
A5 prøve7 3,1-3,5m
A5 prøve8 3,5-3,9m
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A5 prøve10 4,3-4,7m
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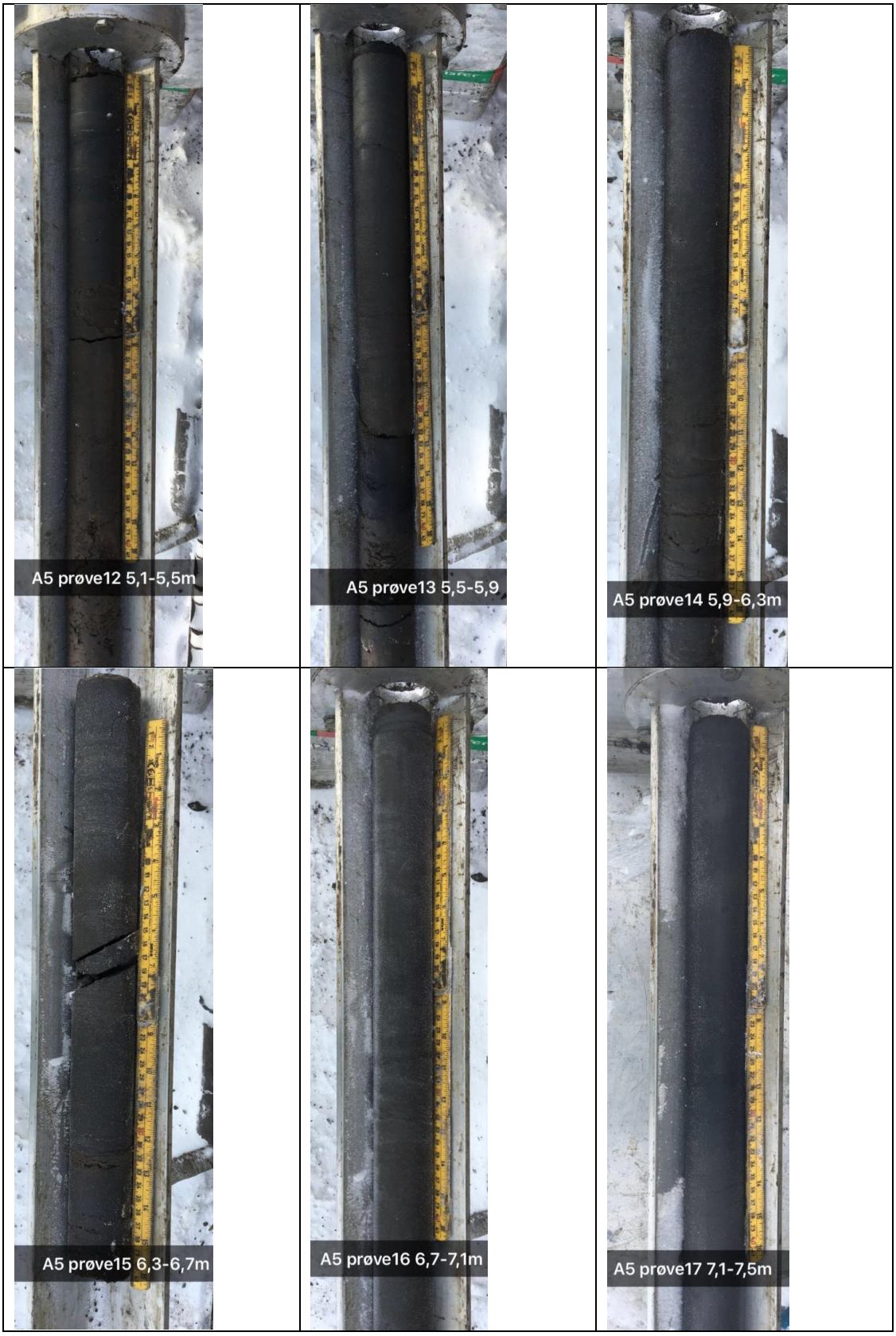
A5 prøve12 5,1-5,5m
A5 prøve13 5,5-5,9
A5 prøve14 5,9-6,3m
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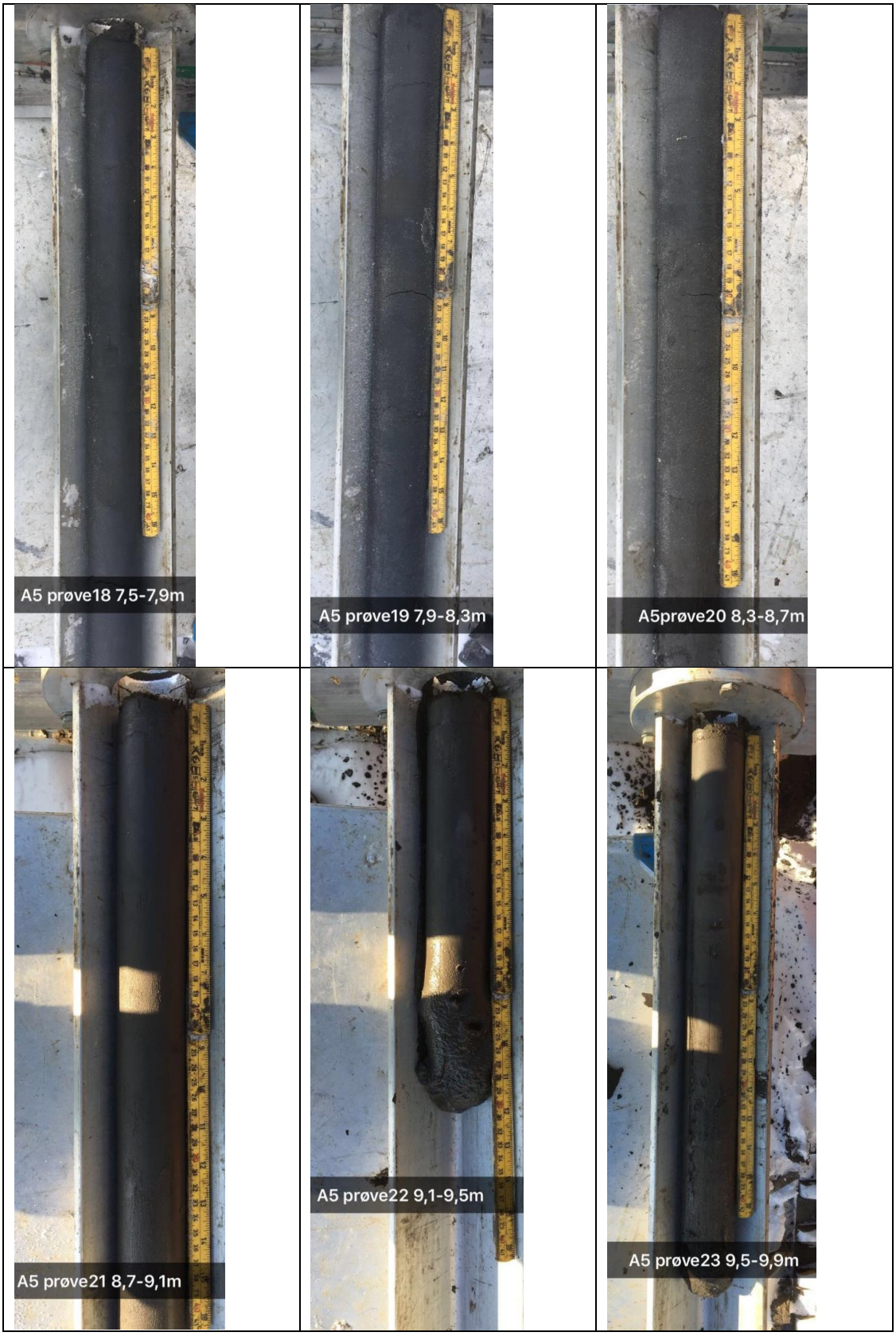
A5 prøve16 6,7-7,1m
A5 prøve17 7,1-7,5m


A5 prøve18 7,5-7,9m
A5 prøve19 7,9-8,3m
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A5 prøve21 8,7-9,1m
A5 prøve22 9,1-9,5m
A5 prøve23 9,5-9,9m


A5 prøve24 9,9-10,3m


A5 prøve 24B 12,2-12,6m


A5 prøve25 12,6-13,0m

NGTS

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Distribusjon/*Distribution* ÅPEN: Skal tilgjengeliggjøres i åpent arkiv (BRAGE) / OPEN: To be published in open archives (BRAGE)		
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Kommune/*Municipality* -	**Feltnavn/*Field name*** Adventdalen
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