DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE **RAPPORT 2025/21**

Geochemical data collection in Villestrup Nret24, 2021-2025

Lærke Thorling, Hyojin Kim, Rasmus Jakobsen,
Denitza Voutchkova, Jens Aamand & Birgitte Hansen

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1. Introduction

The field work in the Villestrup area was designed to address the following working hypotheses for the biogeochemical investigations, within the framework of the Nret24 project:

-Infiltration of nitrate to the chalk aquifer occurs through sandy parts of the Quaternary top layers or though faults in the marl layer
-Nitrate reduction occurs in the chalk aquifer, and redox interfaces can be identified.
-The nitrate reducing zone (redox zone B) has a large extent in chalk aquifers.
-The double porosity of the chalk aquifers (and the impact on the 3D pattern of the redox conditions) plays creates a significant pattern of oxic fractures and reduced matrix.
-Rate experiments using the acetylene block method on undisturbed unconsolidated sediment core samples can give reliable N-reduction rates.
-In some areas nitrate reduction takes place in Quaternary sediments where we know that there is nitrate in the underlying chalk aquifer

The specific target for making new wells was to elucidate these hypotheses:

-The nitrate reduction capacity of the top Quaternary layer in some areas has been depleted; thus, the underlying chalk/limestone aquifers are vulnerable.
-The clay layer between the Quaternary layer and the limestone/chalk layer is deformed and not necessarily thick or continuous; thus, it does not necessarily play a role as a protective layer.
-Denitrification rates in the chalk/limestone are extremely slow; thus, the redox interface can be very deep and often redox type B water is developed.

This report summarizes the procedures for the fieldwork and the resulting field and laboratory data from groundwater samples, sediment chemistry, and reaction rates for denitrification.

2. Methods

Two kinds of investigations were used in the Villestrup area. Firstly, water samples were collected aquifer and analysed for main constituents from existing wells with previous data showing nitrate > 1 mg/l in the chalk. Samples from these wells should illustrate variations with depth over the long screens.

Secondly, shorter wells were made in the quaternary sediments for collecting water and sediment samples at different depths, to elucidate redox conditions and nitrate reduction rates.

2.1. Field campaign planning

To select the representative points of the study catchment, preliminary characterization of the subsurface structure and nitrate transport and fate was done using existing data.

From JUPITER

-Geology from description of boreholes

-Groundwater table

-Groundwater chemistry, especially nitrate

From Kortforsyningen download ([https://download.kortforsyningen.dk/ now moved to Datafordeler.dk](https://download.kortforsyningen.dk/)):

-DHM, the digital elevation model (DEM) for Denmark

-Satellite image or land use/cover info

From the geological interpretation of the area including the new tTEM geophysical data from the WSP campaign (Sandersen, 2023)

From the DK-model

-Simulated flow paths

-Groundwater table depths

Based on this preliminary hydrogeological analysis, we wanted to test the hypotheses (se chapter 1) for the spatial distribution of nitrate and the associated geochemical processes in the subsurface. A contractor, Ejlskov A/S, was made responsible for all contact with the landowners and the well-owners. The contractor also facilitated the fieldwork and was responsible for the logistics and drilling of new wells.
Based on the compiled data, the drilling locations were selected in the following steps:

1. Data interpretation
   - Geological interpretation of the tTEM data (Sandersen, 2023)
   - Redox interpretation of the sediment colour records

2. Pre-selection of focus areas
   - Most representative areas in terms of N pathways

- Feasibility of getting field data
- Accessibility

3. Selecting focus areas

- Discussion among participants from Geochemistry, Hydrology, and Surface departments at GEUS

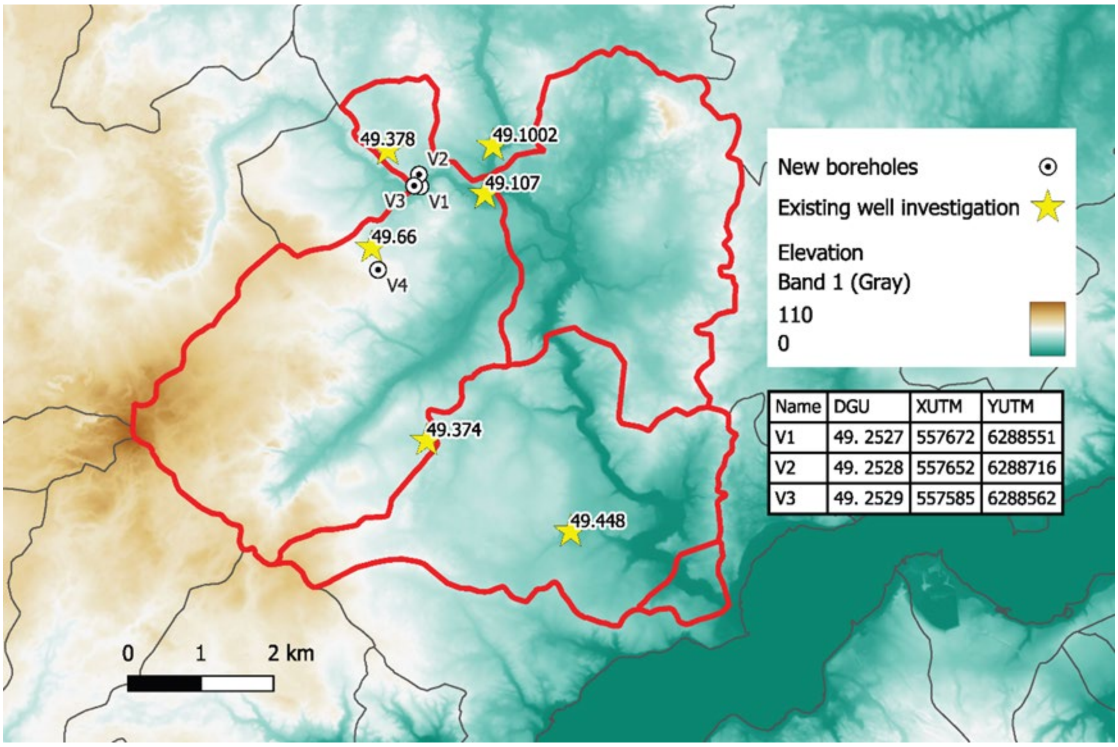
2.2. Sampling from existing wells placed in chalk.

Table 1 shows the wells that were used for sampling groundwater inflow from the chalk aquifer. Most of the wells have an open borehole in the chalk aquifer as shown in appendix 1, where the water from the fractures in the chalk, can flow into the well. Well DGU no. 49.448 and 49.1002 have a PVC screen.

*Tabel 1. Existing Wells sampled April/May 2023. WW: water works wells. Water table from Jupiter, and depths as meters below surface (m b.s.). Wells with open boreholes are marked by *.*

ID - DGU	Sampling	Samples	Water table Jupiter	Water table On day of sampling	Top of chalk	Depth of well	Sampling Depth	Use
No.	Date	No.	m b. s.	m b. s.	m b. s.	m	m b. s.	
49.378*	25-05-2023	4	17.0	17.35	18.6	54	30.5 to 53.0	Irrigation
49.385*	26-04-2023	4	30.6	n.a.	27.5	46	33.0 to 45.0	Irrigation
49.386*	01-05-2023	3	24.0	23.6	39.0	85	52.0 to 84.0	Irrigation
49.448	26-04-2023	3	7.3	7.33	29.0	83	47.0 to 65.0	Drinking water (WW)
49.594*	27-04-2023	3	19.0	17.25	14.0	44	31.0 to 41.0	Irrigation
49.965*	27-04-2023	4	39.5	40.07	69.5	108	93.0 to 106.8	Drinking water (private)
49.1002	24-04-2023	2	3.5	3.16	35.0	75	61.0 to 73.0	Drinking water (private)

The sampling took place from April 26th to May 25th, 2023. Figure 1 shows the geographical distribution of these wells.



Name	DGU	XUTM	YUTM
V1	49. 2527	557672	6288551
V2	49. 2528	557652	6288716
V3	49. 2529	557585	6288562

Figure 1. Map of existing wells sampled April/May 2023, and new boreholes V1-V3, drilled May 2023.

The permanent pump used for water abstraction for drinking water or irrigation was removed the day before sampling, so the water in the borehole had time to stabilise, after the disturbance caused by the removal of the pump. No prepumping was done in the wells after removing of the permanent pumps. Only when the permanent pump was removed, it was possible to install the low flow sampling tubes, special designed for this purpose, see Figure 2 to Figure 4.

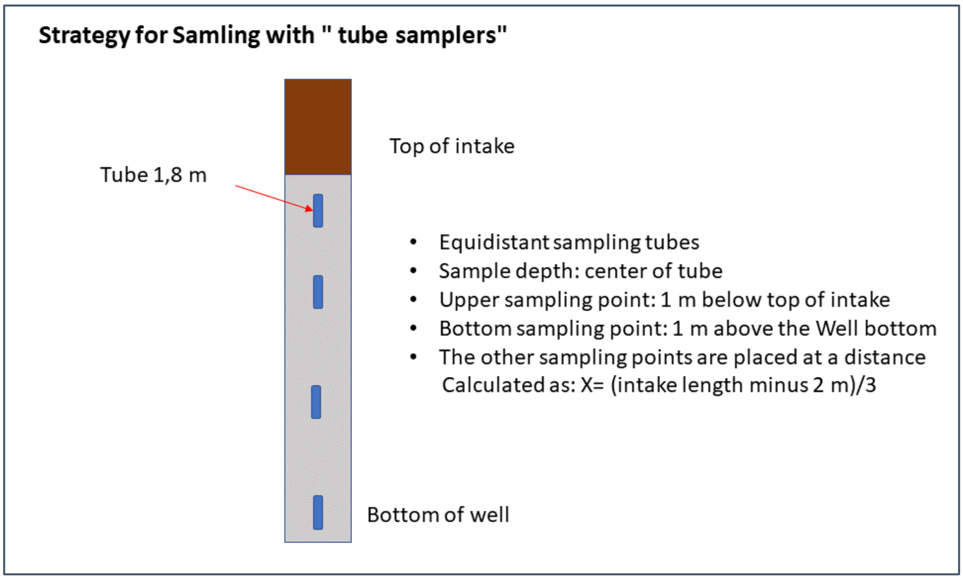


Figure 2. Sketch of the concept for sampling of existing wells with a long open boreholes/screens by sampling tubes. The sampling depth is defined as the centre of the 1.8 m long tube. Personal communication Ejlskov. (Note Danish notation of tube length in sketch)

Figure 3. As preparation for the depth specific sampling, the permanent pump must be removed. May 1st, 2023, DGU 49.386.

Figure 4. Sampling devices for depth specific sampling in existing wells with a long open borehole/intake in the chalk aquifer. May 1st, 2023, DGU 49.386.

Figure 2 shows a sketch of how the tube-sampler was placed in each of the seven wells. In each tube a small plastic bag collected samples of up to 500 ml groundwater, and this groundwater could be used for field measurements and aliquots for later analysis in the lab at GEUS in Copenhagen. Subsamples were immediately places in a cooling box. Sampling with the tube sampler lasted 4-8 hours per well. Each of the samplers have their own low flow pump, that very slowly drags water from the well to the tube. The idea was that the flow into the sampler should be lower than the horizontal groundwater flow that goes through the open borehole/screen in the well. To obtain a level specific sampling it is required that the flow in the well is predominantly horizontal. For long screens this implicates that there is hydrological contact between all layers with inflow to the well, and thus no jump in the hydrological pressure. This should be kept in mind when interpreting the data.

2.3. Borehole drilling and sample collection

In May 2023 4 sites were selected, where water samples and sediment cores were taken during the drilling process using a Geoprobe, percussive drilling rig by Ejlskov, see Figure 5.

Figure 5. Drilling well V2, DGU. 49.2528, with med Geoprobe May 17th, 2023, DGU. 49.2528

Tabel 2. New wells drilled May 2023, location see Figure 1. Map of existing wells sampled April/May 2023, and new boreholes V1-V3, May 2023. Note the core depth is shallower than the maximum water sampling depth, which is also reflected in the geological descriptions in Appendix 2.

DGU No.	Local ID	Date	Depth of coring [m b.s.]	Water Samples	Core samples	Water Sampling Depth [m b s.]
49.2527	V1	03-05-2023	15.56	11	9	2.5 to 22.5
49.2528	V2	02-05-2023	12.20	5	5	12.5 to 22.5
49.2529	V3	01-05-2023	12.20	7	9	10.5 to 22.5
49.2530	V4	04-05-2023	12.20	4	8	4.5 to 22.5

Tabel 2 gives an overview of the depths and numbers of samples taken. Core samples were taken in the upper groundwater, due to issues with loss of sediment, in the saturated zone while sampling for sediment. Water samples and samples for dissolved gases were collected only from the saturated zone. The groundwater was pumped by an inertia-pump into a beaker and abstracted from the groundwater through a short 25 cm screen at the bottom end of the Geoprobe drilling-rod as it was retracted. No precise assessment of the groundwater table was possible with this drilling method.

The inertia-pump works by lifting the tubing, equipped with a one-way valve at the bottom, up and down and thus lifting the water from the groundwater to the surface. This can be done automatically or by hand.

The core samples were cut and wrapped with aluminum tape in the field for the following purposes: pore-water chemistry (9cm-long), nitrate reduction rates (25cm-long), sediment geochemistry analysis (varying length), and lithological description (varying length). Except for the lithology samples, all the core samples were stored in a cooling box in the field and samples for sediment geochemistry analysis were frozen the same day.

2.4. Field measurements and sampling all well types.

Field measurements for electrical conductivity (EC), pH and dissolved O_2, NO_3^- and Fe^{2+} were performed. Electrodes were used for conductivity (EC), pH and dissolved O_2, and these measurements were as far as possible performed as semi-online measurements, as the pump sent the water directly into a beaker, where the electrodes were placed. The electrodes were calibrated daily according to standard methods. Colorimetric measurements were done on a WTW Photoflex instrument in the field, Figure 6, with daily calibrations.

Water samples for Fe^{2+} were filtered assuring the water having no contact with the atmosphere (by filling a syringe directly from the sample (for the permanent wells) or the online flow (for new wells) when possible, and filtering through a 0.2µm syringe-filter. The first couple of millilitres were discarded.

Results of the field measurements can be found in chapter 3 and appendix 3.

Besides the field measurements water samples were also taken, see Table 3.

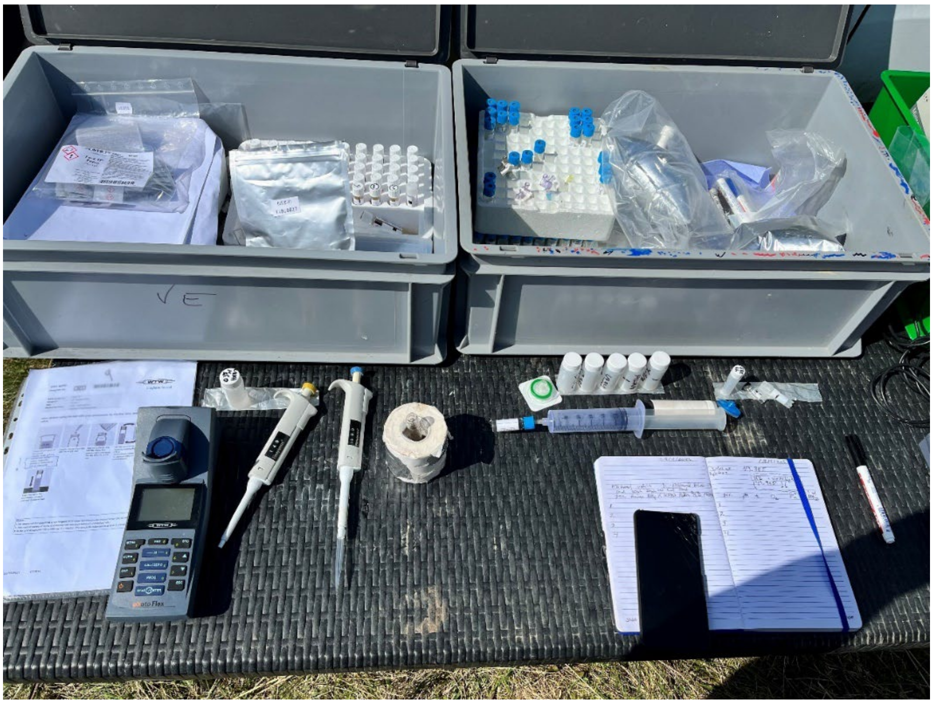


Figure 6. Equipment for field measurements and sampling vials.

Tabel 3. Water samples collected from existing and new wells April/May 2023, sample size, filtering and preservation.

What	Vial	Filtration
DOC	20 ml scint. Vial	Filtered 0.45 µm PES
Alkalinity	20 ml scint. Vial	filtered 0.2 µm CA
NH4+	20 ml scint. Vial	Unfiltered
Anions	20 ml scint. Vial	Unfiltered (cooled and frozen in the evening)
Cations+trace elements	5 ml scint. Vial	filtered 0.2 µm CA
Water isotopes	2 ml glass vial	filtered 0.2 µm CA
Nitrate 15N	2 ml plastic vial	filtered 0.2 µm CA
Gas Sample	6 ml Exetainer®	

2.4. Water chemistry analysis in the lab

At the GEUS laboratory all samples were analysed according to the standard methods used by GEUS inorganic laboratory at the time of the analysis. All water and sediment samples have been stored refrigerated or frozen until analysis.

Water samples were analysed for:

-Anions: F^-, Cl^-, Br, NO_3^-, PO_4^{3-}, SO_4^{2-},

-Alkalinity: HCO_3^-

-Metals/nonmetals: Na, K, Mg, Ca, Fe, Mn, Si, Al, Cu, As

-Ammonium, NH_4^+

-Dissolved inorganic and organic carbon: TOC, TIC.

-Water Isotopes: δO18, δD.

The overall methods were

-Anions by an ion chromatography (IC)
-Ammonium by a Flow Injection Analysis (FIA)
-Dissolved inorganic and organic carbon by an Infra-red (IR) detection on a Shimadzu instrument
-Cations and trace elements by an Inductively Coupled Plasma - Mass Spectroscopy (ICP-MS)
-Water isotopes by a Cavity Ring Down Spectroscopy CRDS. No further description of laboratory methods will be provided here.

The core samples were centrifuged to extract pore water for the pore water chemistry analysis at the GEUS lab. The centrifuged water yield varied, and analyses were prioritized in the following order: 1) Anions 2) ammonium 3) Dissolved inorganic and organic carbon 4) Cations and trace elements and 5) Water isotopes.

All results are presented in Chapter 3 and the appendixes.

2.5. Gas samples and chemistry analysis

The dissolved gases N_20 and CH_4 were measured in the laboratory on gas samples. The gas samples were prepared in the field by transferring 50 ml of water into a syringe filling it to 60 ml with N_2 gas from a gas bag, closing the syringe, shaking for 1 min, and then transferring the equilibrated gas to an evacuated vial (Exetainer®). The concentration of the gases was then calculated based on Henry's law constant for the field temperature of the equilibration, between air and gas.

2.6. Sediment chemistry analysis

The Fe(III)/Fe(II) can serve as a proxy for the redox state of the sediment, and to provide this the sediment was extracted anaerobically overnight using formic acid. The formic acid can extract very reactive Fe(III) (oxides) and Fe(II) carbonate and displace cation exchangeable Fe^{2+} and Fe^{3+}. The extracted amounts of Fe(II) and the Fe(tot) (total Fe) were determined spectrophotometrically using Ferrozine, Fe(II) directly and Fe(tot) after reduction with hydroxylamine hydrochloride. Fe(III) from less stable Fe-oxides, and Fe(II) compounds soluble at pH 3 were determined by extraction using formic acid at pH 3

2.7. Nitrate reduction rate measurements.

Denitrification rates were determined by the acetylene-blocking method (Smith et al., 1978). Briefly, 100 g sediment was added to a 116 ml bottle with 20 ml 1 mmol nitrate solution under constant N_2-flushing and sealed using a 1 cm-thick butyl rubber stopper. Acetylene gas was added with a syringe to a concentration of 10% in the headspace to inhibit the last step in denitrification. The resulting N_2O accumulation in the headspace was followed for up to 4 weeks. Denitrification rates (mmol NO_3/ l/ yr) were calculated from the rates of N_2O production in mmol per g of incubated sediment per year multiplied by 2 (2 N/N_2O) assuming that there are 5.4 kg of sediment per liter of porewater. For all samples both an initial 1st rate and a later 2nd rate has been determined, as illustrated in Figure 7.

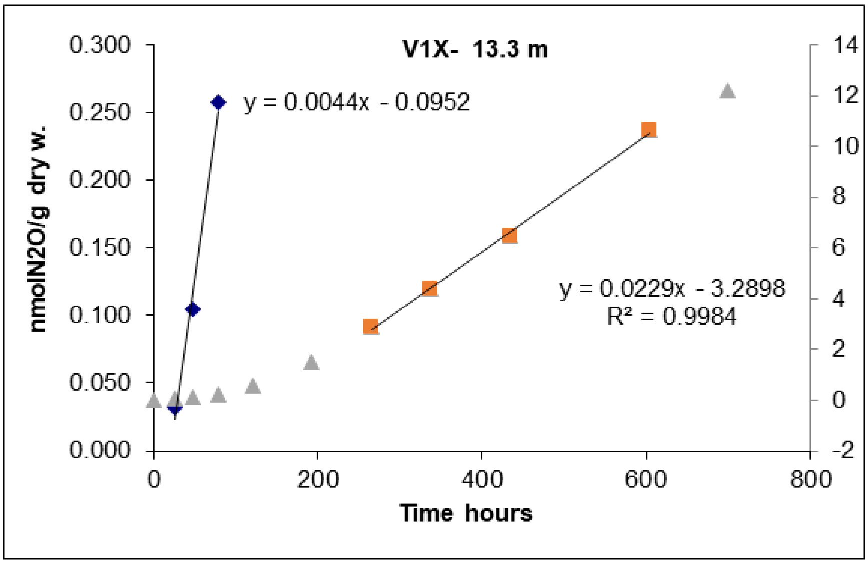


Figure 7. An example of an initial 1st rate (blue diamonds, left Y-axis) and a later 2nd rate (orange squares, right Y-axis) for an anoxic incubation (core segment). Grey triangles show on the right Y-axis all the data and includes the higher values.

An additional experiment was setup to investigate whether rates determined in slurries as described above differs from rates determined using intact sediment cores. Briefly, 4 cm intact standard cores (D 4.6 cm) or macro cores (D. 3.1 cm) were placed in 120 ml caviar glasses. A 20 ml 1 mmol nitrate solution were then distributed on the core surface under constant N2-flushing, and the glasses were closed with metal screw lids equipped with valves for sampling. Acetylene gas was added with a syringe to a concentration of 10% in the headspace and the N2O development was followed for up to 14 days, after which denitrification rates were calculated as described above.

In total, four boreholes were drilled, see Table 2. However, it was only possible to obtain samples below the redox boundary at one well, V1. Since oxygen was present in all samples from V2, V3, and V4, denitrification rates from these drillings were also determined under aerobic conditions. This was done by injecting atmospheric air into the bottles to a concentration of 2-4%. This step was omitted for V1, including the upper aerobic samples above the redox boundary.

For few of the very closely spaced samples intended as double determinations, due to leaks or rapid oxygen consumption, we ended up with similar sediments, but very different oxygen levels allowing for a preliminary comparison of the effect of oxygen on the measured rate.

2.9. Lithology description

Geological descriptions of the sediment samples were carried out at the laboratory at GEUS and are shown in Appendix 2.

3. Results

This chapter focuses on presenting the results from the chemical analyses, the nitrate reduction rate measurements and discussing the quality of the measurements. All results are reported in appendixes to this report.

The water chemistry data can be found placed in the Dataverse at GEUS https://dataverse.geus.dk/dataverse/water-resources in an Excel file named: *All_wateranalysis_Villestrup _2024.xlsx*.

3.1. Results of the field work and laboratory measurement.

For the laboratory analysis, where enough parameters have been measured to make it feasible to make a charge balance, the error, calculated using PHREEQC, is mostly within 5%, with a few that are higher, up to 10%. This is only an indication of the overall quality for major ions, errors on minor ions are not revealed by charge balance errors.

The quality of the field measurements is evaluated by comparing nitrate in the lab with the field measurements for nitrate and oxygen, se Figure 8 and Tabel 4. For nitrate it is very clear that the field measurements generally are 10-20 mg/l lower than the lab measurements, except for the wells DGU nr. 49.1002, and DGU nr. 49.448 that are characterized by a low nitrate content.

It is noteworthy that for well DGU nr. 49.594 there is no nitrate according to the field measurement, but around 20 mg/l according to the lab measurement. In addition to this there in this well is 145-202 µg/l ammonium which is normally associated with reduced water, redoxtype C or D. Also, the CH_4 concentration in has been measured to 3-4 mg/l at the three sampling points indicating strongly reduced water. It seems probable that this is an indication of internal flow within this well, implying that the water is mixed, as the concentrations for all parameters are the same when the sampling and analytical uncertainty is taken into account.

This raises the general question – to what extent do the samples taken with the low-flow sampling represent different levels in the well. Wells 49.1002 and 49.378 show significantly different concentrations of ammonium, sulfate, and other parameters. Well 49.385 shows very small differences between the 4 samples, for the parameters in Table 4, however, the CH_4 concentrations are significantly higher in the upper 2 samples and the Fe concentrations are significantly higher in the sample at 41 m.b.s. Well 49.386 shows a systematic similar nitrate over depth and no ammonium, also indicating mixing. Well 49.448 shows much higher CH_4 in the top sample and an increase in Mn with depth indicating that samples to some extent represent different depths. Well 49.965 shows a clear decrease in DOC (6.51 to 1.58 mg/l) over depth and an increase in Mn from 0.15 to 0.01 mg/l over depth, indicating samples to some extent represent different depths, in spite of very small variations in nitrate and sulfate concentrations.

Overall, it must be recommended that if site specific samples are to be taken in long intakes in open boreholes or screens this method does not give sufficient clear separation of the water at different levels due to internal mixing of the water arising from differences in hydrological pressures in the different fractures which support the well with water. Instead, traditional separation pumping with is recommended (Fjordbøge, 2016).

Despite taking every possible caution all field measurements of O2 showed a high oxygen content of the water, which seems unlikely to be true in groundwater together with ammonia and methane. This indicates that the bags in contrast to what was promised were not sufficiently airtight.

Tabel 4. Results from existing wells on nitrate, oxygen, sulfate, and ammonium.

Well	Depth [m b.s.]	SO4 mg/l	Nitrate lab	Nitrate field	NH4 ug/l	oxygen field
49. 1002	61	94.5	1.32	1.3	204	7.3
49. 1002	73	135	1.3	1.3	678	7.5
49. 378	30.5	14.5	45.5		244	
49. 378	38	19.2	64.9	46.9	21	10.1
49. 378	45.5	18.4	64.6	50.0	10	10.4
49. 378	53	18.2	64.6	45.2	8	10.3
49. 385	33	47.9	29.7	14.2	< 6	10.3
49. 385	37	47.5	30.5	19.0	< 6	9.1
49. 385	41	47.1	31.1	19.5	< 6	10.4
49. 385	45	47.1	30.2	50.5	< 6	10.7
49. 386	52	25	35.4	21.7	< 6	
49. 386	68	24.8	36.7	19.5	< 6	
49. 386	84	24.2	41.3	23.9	< 6	
49. 448	47	35.7	3.88	<1	< 6	9.0
49. 448	59	37.4	4.16	<1	< 6	9.1
49. 448	65	37.6	3.68	<1	< 6	9.6
49. 594	31	55	18	<1	202	10.5
49. 594	36	55.5	18.7	<1	168	11.4
49. 594	41	54.6	19.6	2.7	145	11.5
49. 965	93	28.4	38.2		< 6	
49. 965	97.6	29.5	41.3	31.0	< 6	10.4
49. 965	102.2	29.1	42.1	30.6	< 6	9.9
49. 965	106.8	29.2	40.8	27.9	< 6	9.3

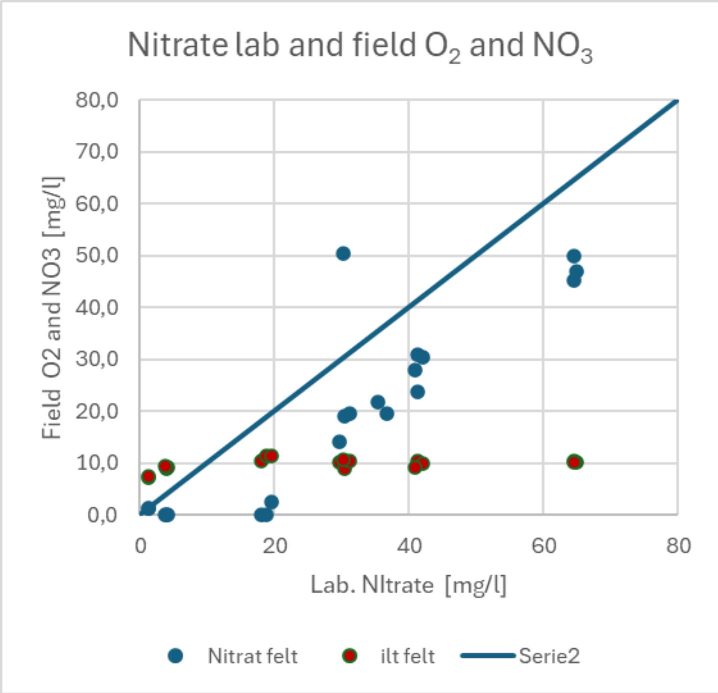


Figure 8. Nitrate in the laboratory, compared to field measurements of oxygen (red) and nitrate (blue), in existing wells April/May 2023. The line "serie2" show x=y, that the field and lab measurements should follow if the analytical quality was OK.

Comparison with the overall groundwater quality in the existing wells

Table 5 shows the overall groundwater quality of the existing wells from former water controls at commercial accredited laboratories. Three of the wells have no water quality data in the database. The analyses confirm, that DGU nr. 49.1002 has old and reduced water, with relative high Na and Cl concentrations and low nitrate. The electrical conductivity resembles the top sample from our low-flow sampling, indicating that the inflow from the lower part is a small fraction of the pumped water. The reduced conditions in DGU 49.448 are also confirmed. DGU nr. 49.378 has far more nitrate now than in 1979, which could be expected since the general nitrate leaching has been increased, and the water in the screen would be some decades old (Hansen et al 2017) Another explanation is differences in mixing of the water when the pump is running. For DGU nr. 49.965, chloride, nitrate, and sulfate concentrations in 2012 were similar to those in our samples. The ammonia was below the detection limit at both sampling times.

Table 5. Chemical water analysis from the existing wells, made at commercial laboratories.

	dato	pH	ledn	ilt	NO3	NH4	SO4	Cl	PO4	F	Na	K	Mn	Fe	DOC	Sr
DGU nr.			mS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l
49.1002	05-05-2010	7,81	116		3,7	0,14	82,1	200	0,12	0,77	139	2,8	<0,01	<0,02	1	
49.378	26-01-1979	8,1			10			21						0,01		
49.385	ingen															
49.386	ingen															
49.448	28-05-2020	7,7	35		2,2	0,019	38	22	<,01	0,3	8,6	1,6	0,01	<0,01	0,35	2000
49.594	ingen															
49.965	17-04-2012	7,7	37,8	8,18	42	<0,006	28	25	0,028	0,13	11	0,84	<0,005	<0,01	0,65	

The same test for bias on the lab/field nitrate was made for the samples from the 4 Geoprobe wells, where key results are shown in Table 6. The relationship between lab and field results is shown in Figure 9. The same pattern is found; that the laboratory nitrate is systematically higher with about 15-20 mg/l, except for a few samples in DGU no. 49.2529 where more than 75 mg/l was found in the field, where the field measurements is erratically high.

Table 6. Results from four new Geoprobe wells on nitrate, oxygen, sulfate and ammonium.

Well ID DGU no.	Depth m b.s.	SO4 mg/l	Nitrate lab	Nitrate field	NH4 ug/l	oxygen field
49.2527	22.50	44.8	<0.05	0.0	0.027	0.67
49.2527	20.50	44.8	<0.05	0.0	0.044	0.12
49.2527	18.50	40.1	<0.05	0.0	0.010	1.62
49.2527	16.50	44.8	<0.05	0.0	0.023	0.13
49.2527	14.50	44.9	<0.05	0.0	0.052	0.15
49.2527	12.50	44.3	<0.05	0.0	0.022	0.24
49.2527	10.50	29.4	32.2	13.3	0.033	2.21
49.2527	8.50	20.8	65.9		0.075	4.31
49.2527	6.5	22.3	66.0		0.061	4.99
49.2527	4.50	24.6	68.6		0.192	5.44
49.2527	2.5	18.9	107		0.177	5.74
49.2528	20.50	24.9	58.9	39.4	0.077	4.6
49.2528	18.50	19.4	87.0	63.3	0.148	5.37
49.2528	16.50	16.4	81.6	73.1	0.082	8.16
49.2528	14.50	15.7	68.2	48.3	0.043	7.56
49.2528	12.50	15.1	55.9	37.2	0.295	0.26
49.2529	22.5	30.7	3.26	0.0	0.254	0.07
49.2529	20.50	34.3	34.7	43.8	0.207	0.42
49.2529	18.50	30.3	60.2	34.1	0.124	8.17
49.2529	16.50	29.1	67.3	116.9	0.107	8.86
49.2529	14.50	29.5	65.1	141.7	0.109	8.78
49.2529	12.50	28.8	62.1	46.5	0.352	6.17
49.2529	10.50	25.3	43.0	85.9	0.198	4.95
49.2530	22.50	25.5	71.5	54.5	0.015	5.8
49.2530	20.50	26.9	72.9	56.2	0.034	8.78
49.2530	6.50	34.2	28.6	21.3	0.130	6.87
49.2530	4.5	26.6	25.5		0.008	8.73
49.2530	7.00					
49.2530	8.00	23.9	49.3		<0.005	
49.2530	9.00	32.2	14.4		1.369	
49.2530	10.00	19.5	35.2		<0.005	
49.2530	11.00					

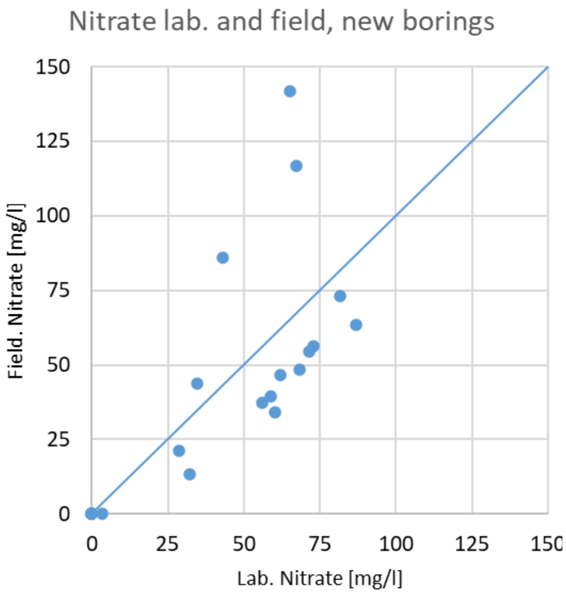


Figure 9. Nitrate in the laboratory compared to field measurements in the new Geoprobe wells May 2023. The line show x=y that the field and lab measurements should follow if the analytical quality was OK.

Porewater samples, pumped versus centrifuged

The dataset from Villestrup contains water samples produced by pumping using the Geoprobe SP15 system and water samples extracted from sediment cores by centrifugation. There are some overlaps making it possible to compare the two water types for some of the parameters.

Selected parameters for the four new wells are plotted in Figure 10, Figure 11 and Figure 12.

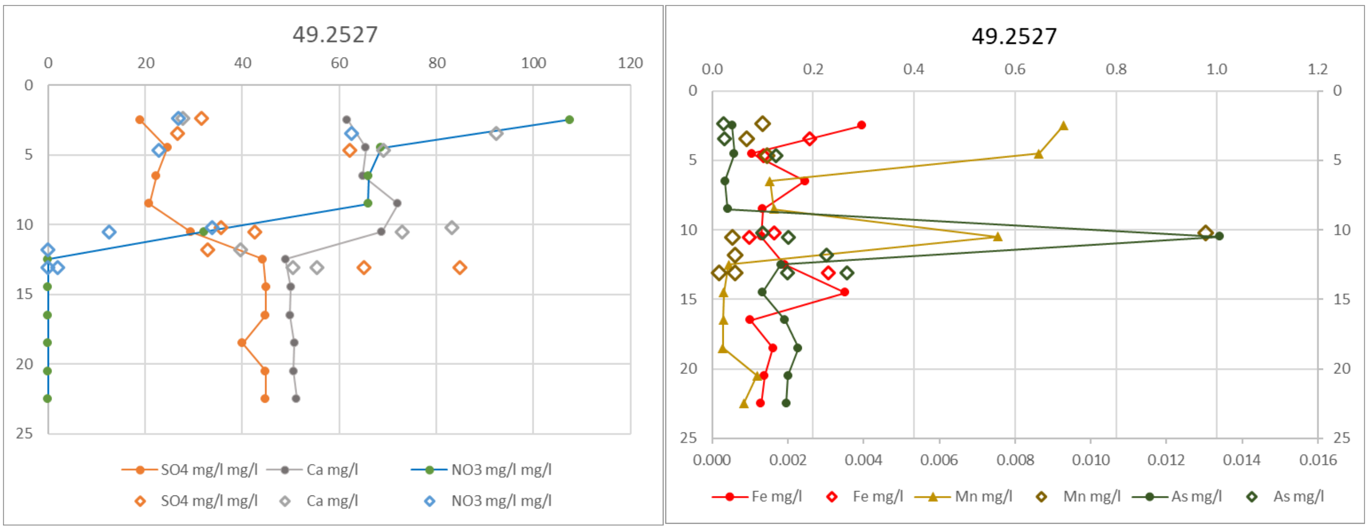


Figure 10. Depth plots (Y-axis, meter below surface) of selected parameters from DGU nr. 49.2527, As is plotted on the lower axis in the right diagram. Small, closed symbols are pumped water, large open symbols are pore water.

DGU nr. 49.2527 is the well with the largest overlap. The values are not the same at all coinciding depths. However, considering the positions of the well for cores and water samples are not exactly the same -there is probably ~1 m between them- and there is some uncertainty on the coring depths as not all cores were completely full, it looks relatively similar. It is a bit surprising that the difference for redox sensitive elements is not larger considering that centrifugation was not conducted anaerobically.

Well, DGU nr. 49.2528 in Figure 11 has no overlap between the sample sets, but for the major ions the values appear to continue from one set to the next. For the minor ions, the concentrations are at least similar.

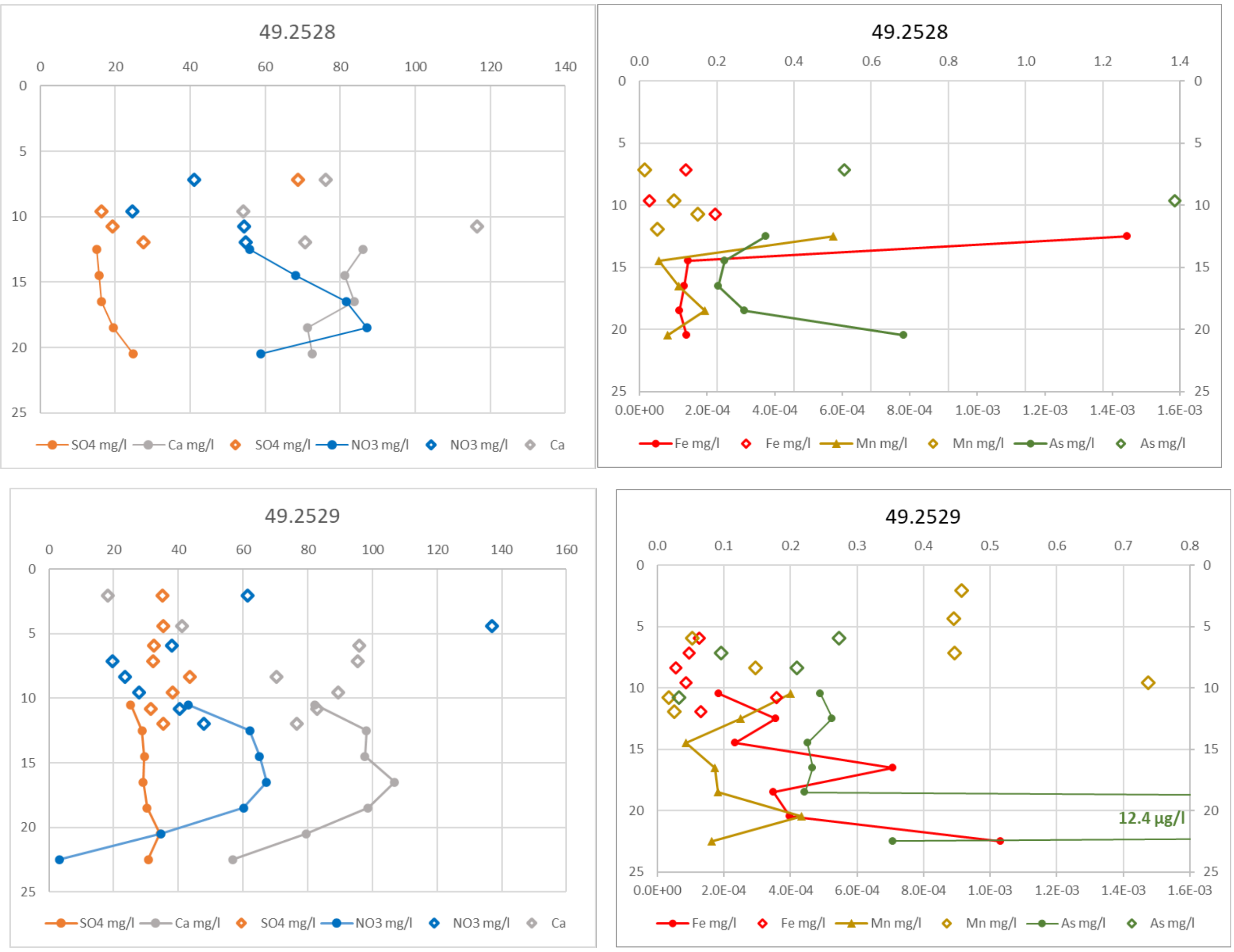


Figure 11. Depth plots (Y-axis, meter below surface) of selected parameters from 49.2528 and 49.2529, As is plotted on the lower axis in the right diagram. Small, closed symbols are pumped water, large open symbols are pore water.

DGU nr. 49.2529 has a small overlap between the sample sets. For the major ions, the concentrations are very similar. For the minor ions, the values appear somewhat similar.

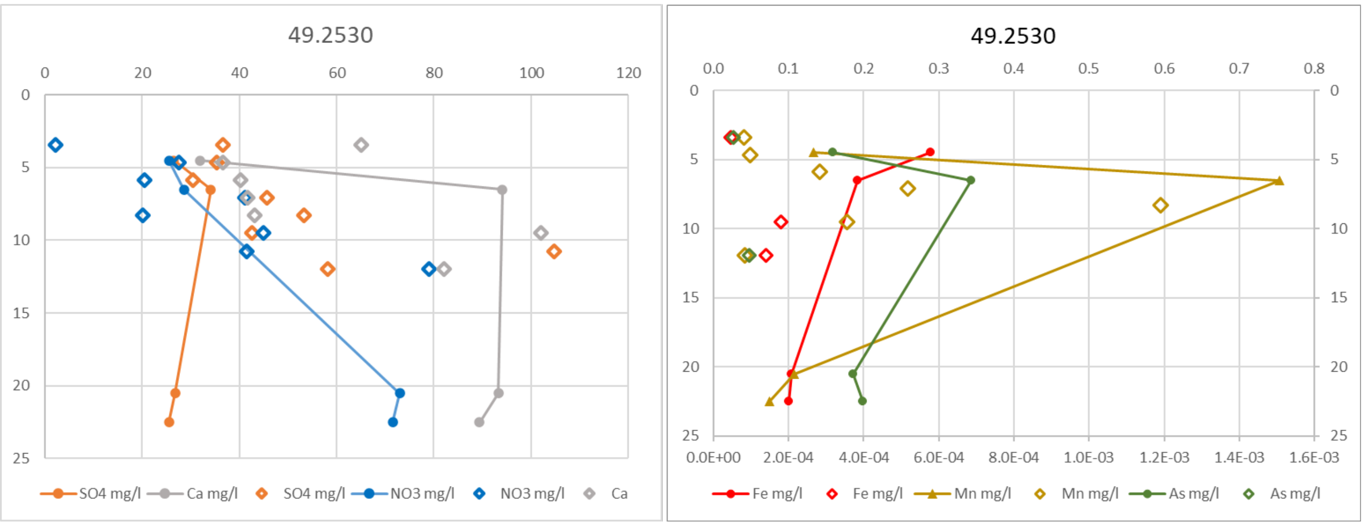


Figure 12. Depth plots (Y-axis, meter below surface) of selected parameters from DGU nr. 49.2530, As is plotted on the lower axis in the right diagram. Small, closed symbols are pumped water, large open symbols are pore water.

DGU nr. 49.2530 has a small overlap between the sample sets, though the SP15 pumped samples have a large gap, presumably due to an interval with fine grained sediments. For the major ions, the concentrations are very similar. For the minor ions, the values appear somewhat similar. e.g., the peak in the Mn concentration coincides.

It can thus be concluded that both types of water samples can be jointly used to describe the groundwater chemistry at each location.

3.2. Results of the denitrification experiments in Villestrup

The cores were segmented in the field and the segments designated for rate measurements were split so that a part was homogenized and used for the standard slurry measurement. while the other part was used as a short piece of core that was incubated undisturbed in the plastic liner. The sediments that were taken from the oxic zone were incubated with a small amount of oxygen. The results of the denitrification rate measurements in the samples with an oxygen amount adjusted to 2-4% are plotted in Figure 13. For the juxtaposed (double) samples measured, where the redox conditions were comparable, the measured rates are generally quite close. For DGU nr. 49.2528 there is a large difference between the core and the slurry, with the rates measured in the slurry are ~10 times higher. For DGU nr. 49.2529 and 49.2530 the rates of the slurry samples are ~2 times higher. Samples that for some reason ended up not having the intended oxic/anoxic conditions have been taken out in the figures, but the values of these samples with different oxic status are compared in Table 7.

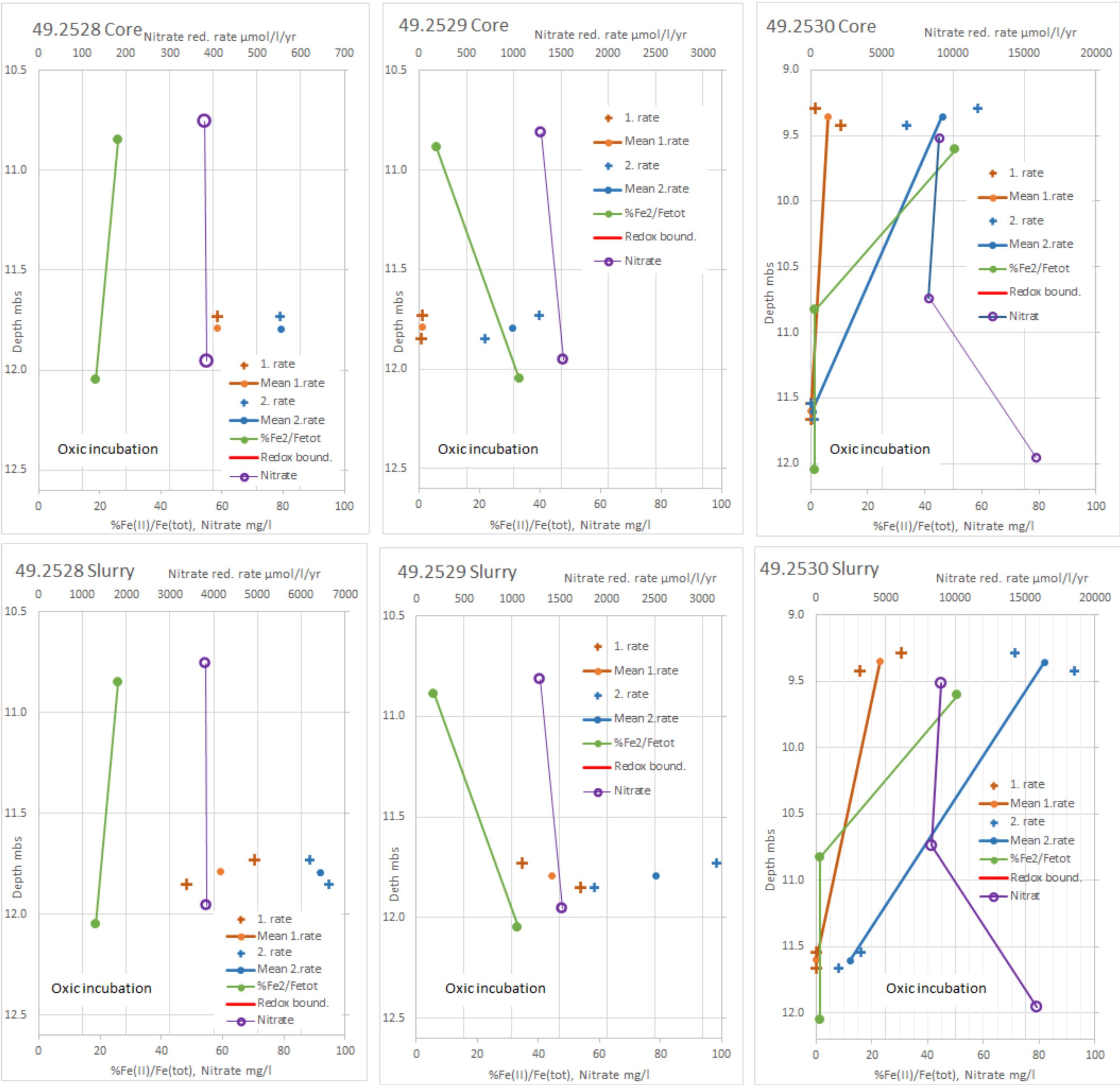


Figure 13. Rates measured by the acetylene block method in oxygen (2-4%) containing incubations of core segments and slurried samples. The % Fe(II)/Fe_{tot} and the nitrate concentrations are included to indicate that all samples are from above redox front.

The results of the denitrification rate measurements in the samples incubated without oxygen are plotted in Figure 14. The two top measurements are actually from sediment that was originally oxic as indicated by the redox boundary.

Also, for well DGU nr. 49.2527 the two juxtaposed samples have rates that are relatively close for most depths. Surprisingly, it appears that the differences are larger for the slurried samples. The difference between the core and slurry incubation rates varies; for some samples the slurry rates are around twice as high. For others the slurry rate is ~5 times higher. Seen separately the variation in the rates in the originally anoxic part of the sediment is relatively small.

The anoxic rates (Fig. 14), especially the early (1. rate) rates are high where the sediment naturally contains nitrate, indicating that microorganisms that can conduct nitrate reduction are present in relatively high numbers. This does not necessarily mean that the sediment was nitrate reducing, as around half of the microorganisms reducing oxygen can also reduce nitrate.

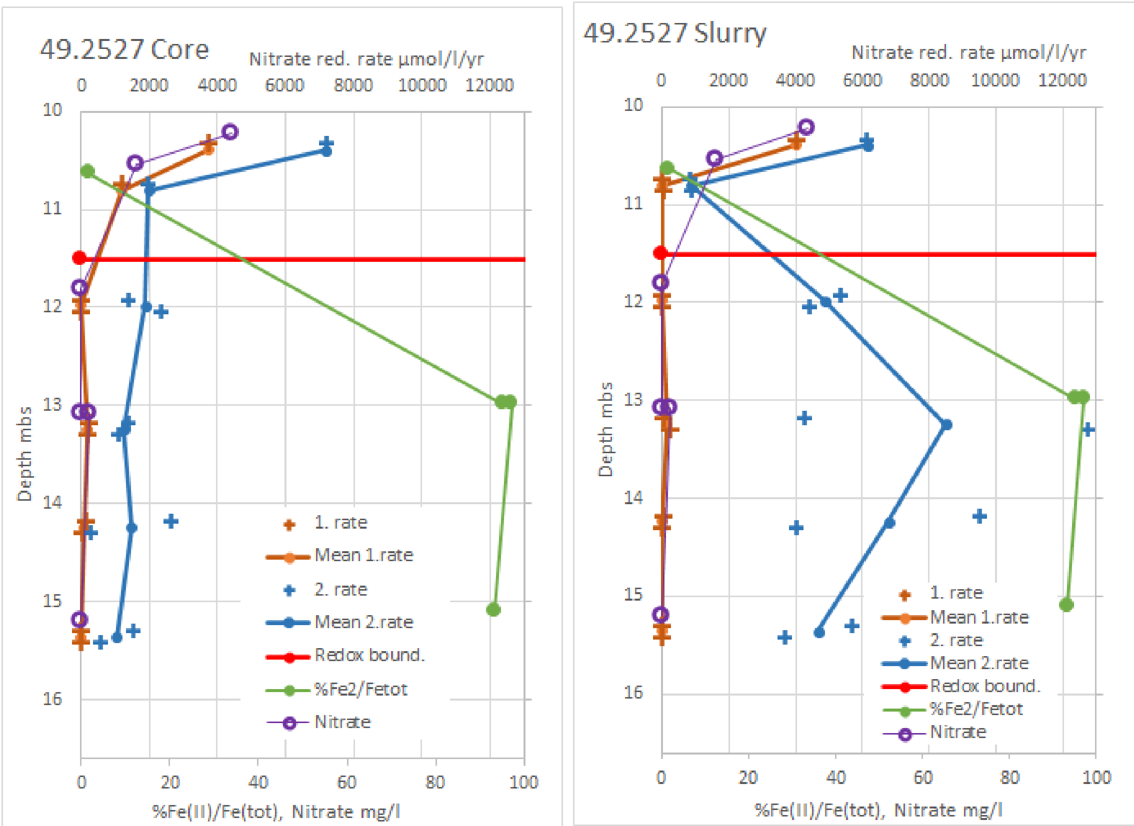


Figure 14. The rates from DGU nr. 49.2527 where all samples were incubated without oxygen. The % Fe2/Fe$_{tot}$ and the nitrate concentrations were used to place the redox boundary.

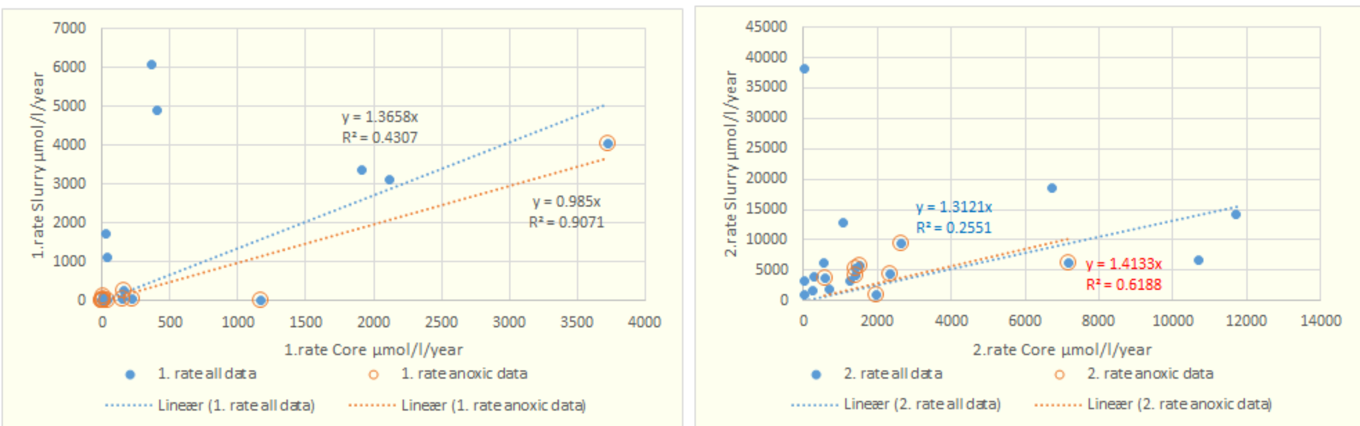


Figure 15. The relation between rates measured in slurries and in juxtaposed core segments for all data and for anoxic incubations alone. The slope of the fitted lines indicates the overall difference between the rates measured by the two methods.

Below the redox boundary the 1st rates are very low, showing that the initial population of nitrate reducers is small. The much higher 2nd rate shows that the electron donor in the sediment is reactive, and the nitrate reducer population increases if nitrate is present.

The slurry and core incubation rates for all the measurements are compared in Figure 15. The slope of the fitted lines indicating the overall difference between the rates measured by the two methods is relatively small. However, especially when all the data are included, there is a huge variation, also seen in the relatively small R^2 values.

Because it was not always possible to control the oxygen level as intended there are a few examples where we can get a preliminary indication of the effect of oxygen on the rates. These measurements are shown in Table 7.

Tabel 7. Comparison of rates measure in juxtaposed sediments with and without oxygen.

Villestrup	**Depth**	**O_2**	**1.rate µmol/l/yr**		**2. rate µmol/l/yr**	
DGU nr.	**mbs**	**mg/l**	Oxic	Anoxic	Oxic	Anoxic
Core segment measurements			incubation	incubation	incubation	incubation
492.528	11.85	0.0		1912		10703
492.528	11.73	5.9	409		553	
492.527	10.33	0.2		3722		7183
492.527	10.45	11.3	10		13	
492.527	10.74	0.1		1173		1983
492.527	10.86	7.9	6		6	
Slurry measurements						
492.527	10.33	0.3		4037		6136
492.527	10.45	4.3	132		38174	

This preliminary dataset indicates that for all the core segment incubations the measured rate in the presence of oxygen is far lower for both the "initial" 1. rate (4.7-370 times) and for the later 2. rate (19-550 times). For the slurry incubation the oxic 1. rate is 31 times lower than the anoxic in line with the core incubations, while the 2. rate is higher in the presence of oxygen (6 times), which we consider an outlier, presumably a result of the development of anoxic micro-niches during the incubation. Overall, it appears that rates are much lower in the presence of oxygen.

4. Interpretation

In this chapter an interpretation of the geochemical results will be performed based on integration of data shown in the well panels in Appendix 7 on both water chemistry, sediment chemistry, and greenhouse gas (GHG) analyses including CH_4, N_2O and CO_2. It is only possible to make a tentative interpretation of the redox conditions because the oxygen measurements cannot be trusted due to contamination with atmospheric air during sampling.

4.1 The existing wells in chalk aquifers

The overall evaluation of the water and gas sampling at different levels in the seven existing wells in chalk aquifers in the Villestrup catchment is that the low flow sampling at different depths was probably not able to separate the water sufficiently in all the wells, and some mixing may have occurred.

The geochemical results show nitrate containing groundwater in five of the seven existing wells in all sampled depths. The sampled nitrate containing water is characterized by nitrate concentrations between app. 14-65 mg/l, and sulfate concentrations between app. 15-48 mg/l in levels from app. 30 – 107 m below surface indicating that the chalk aquifers have a high nitrate vulnerability. The risk of internal flow in the wells makes it difficult to conclude to what depth the nitrate actually was present in the groundwater aquifer.

In two of the existing wells reduced nitrate free conditions were seen in all levels from app. 30 – 65 m below surface. In one of the wells (DGU number 49.1002) saltier groundwater is found at the deepest level with increased concentrations of Cl, Br, F and Mg and SO_4^{2-} compared to the freshwater in the other wells. Na was not measured, and it is therefore not possible to tell if the water has a signature of ion exchange. The relative high F indicates long residence time of the groundwater.

The gas concentrations of N_2O vary from app. 0.2 – 18 ppmV. The highest concentrations are found in nitrate containing groundwater which is probably a result of denitrification. Methane was found both in reduced and nitrate-containing water, which could indicate some mixing or the presence of reduced domains in the system. Once formed, methane is relatively stable. Methane concentrations vary from app. 3- 131 ppmV in three of the wells while it was at low concentrations in the rest of the wells.

4.2 The new wells in Quaternary aquifers

Four new successful wells with multilevel sampling down to 22.5 m below the surface in Quaternary aquifers above chalk aquifers were conducted. The new wells had 4-11 water sampling points and 5-9 core sampling points per well. The core samples were both used for pore water extraction for chemical analyses and sediment analyses as the overview in the well panels in appendix 7 shows.

The aquifer redox conditions can be deduced based on integration of field measurements of oxygen, color descriptions of the sediment and laboratory measurements of redox sensitive parameters in the water and Fe(II)/Fe_{tot} analyses of the sediment as described in Hansen et al. (2021).

Overall, the interpretation of the redox conditions in the four new wells shows that oxic and anoxic nitrate-reducing conditions exist in all four wells, and thereby indicative for high nitrate vulnerability of the Quaternary aquifers. In two of the wells (DGU number 49.2528 and 49.2530) the Quaternary aquifer is nitrate-containing and probably oxic all the way to 22.5 m below the surface. In the other two wells a redox interface (transition from oxic to reduced groundwater) is found at about 19 m b.s. (DGU number 49.2529) and at about 11 m b.s. (DGU number 49.2527).

In three of the new wells increased levels of chloride concentrations are found in distinct upper layers down to about 10 m b.s. (DGU number 49.2527, 49.25290 and 49.2530). This is probably due to leaching of road salt as the Na/Cl ratios show inverse ion exchange and Cl/Br ratios > 550. In the other well (DGU number 49.2528) both high chloride and sodium concentrations are found in a certain level of sampling (9.62 m b.s.) here indicating ion exchange due to flow of groundwater into a saltier sediment.

The gas concentrations of N_2O vary from app. 0.02 – 37 ppmV. The highest concentrations are found in nitrate containing groundwater which probably is a result of denitrification, and very low concentrations are found in reduced groundwater. Methane was found both in reduced and nitrate-containing water as in the existing wells indicating that reduced micro-environments are present. Concentrations vary from app. 3 - 67 ppmV.

None of the new wells reached the chalk, though well V2 DGU no. 49.2528, came close.

5. Conclusion

The geochemical investigations in Villestrup cannot be generalized to all chalk aquifers in Denmark, therefore we extended the analyses in Villestrup to other areas:

- A national analysis based on groundwater data from whole Denmark to evaluate where chalk aquifers are in risk of nitrate pollution (Voutchkova et al, 2025).
- Drilling new wells into chalk aquifers was too expensive. Therefore, nitrate reduction rate experiments were performed from chalk outcrops at Stevns (Aamand et at, 2025)

The following conclusions can be drawn from the sampling and laboratory analyses from Villestrup:

- The nitrification rates determined in the laboratory using the acetylene block method showed similar values for juxtaposed (double) sediment samples.
- An additional experiment comparing denitrification rates determined in slurries to rates determined using intact sediment cores mostly corresponded, but with some diverting results. The results show that laboratory analyses of denitrification rates depend on the experimental setup and guidelines on optimal methods for low-rate systems like aquifers are needed.
- Nitrate was measured both with a colorimetric method in the field and in the laboratory. A comparison showed a high degree of uncertainty on the field measurements with 10-20 mg/l lower values in the field measurements.
- The chemical results from the multilevel sampling in existing chalk aquifers indicate that internal flow may occur in the wells, implying that the water is mixed. This indicates that the samples taken with the low-flow sampling did not always represent different levels in the well.

The following conclusions can be drawn from the interpretation of results:

- Integration of results on both water chemistry, and sediment chemistry indicated a high nitrate vulnerability of both the Quaternary and underlaying chalk aquifers.
- High concentrations of N_2O were found in nitrate containing groundwater and indicated risk of GHG emission from the aquifers due to incomplete denitrification.
- The upper part of the investigated Quaternary aquifers had signs of impact from road salt with elevated concentrations of chloride and high Cl/Br ratios.

This study confirmed some of the initial formulated hypotheses listed in introduction:

- Infiltration of nitrate to the chalk aquifer occurs through sandy parts of the Quaternary top layers. The fieldwork can not elucidate the role of nitrate transport through faults in the marl layers.
- Nitrate reduction occurs in the chalk aquifer, but the position of redox interfaces in the chalk could not be identified in the existing wells, most probable due to internal flow in the wells during sampling. Further work on this was done at Stevns, where the double porosity was studied (Aamand et al., 2025)
- The nitrate containing water has a large extent in the sampled chalk aquifers, but due to contamination with atmospheric air, delineation of anoxic nitrate reducing water in the chalk was not possible.
- In some areas nitrate reduction takes place in Quaternary sediments where we know that there is nitrate in the underlying chalk aquifer.
- In some areas the nitrate reduction capacity of the top Quaternary layer has been depleted; thus, the underlying chalk/limestone aquifers are vulnerable as well.
- The clay layer between the Quaternary layer and the limestone/chalk layer is deformed and not necessarily thick or continuous; thus, it does not generally function as a protective layer (Sandersen, 2023).
- Rate experiments using the acetylene block method on undisturbed unconsolidated sediment core samples can give reliable N-reduction rates, and the highest rates are found in the nitrate carrying layers.

6. Literature

Aamand, J., Jakobsen, R., Voutchkova, D., Kim, H., Thorling, L. & Hansen, B., 2025: Denitrification in chalk, Nret24, 2021-2024. *Appendix in: Anker Lajer Højberg, Hans Thodsen, Christen Duus Børgesen (red.) Anne Hasselholt Andersen, Lærke Therese Andersen, Joachim Audet, Eva O. Bach, David Terpager Christiansen, Ditte Asmussen Christiansen, Joel Tirado Conde, Frederik Alexander Falk, Rasmus Rumph Frederiksen, Franca Giannini-Kurina, Jacob Gudbjerg, Birgitte Hansen, Christopher Vincent Henri, Emil Skole Henriksen, Nichlas Hermansen, Carl Christian Hoffmann, Anne-Sophie Høyer, Bo Vangsø Iversen, Rasmus Jakobsen, Margit Styrbæk Jørgensen, Hyojin Kim, Ane Kjeldgaard, Julian Koch, Brian Kronvang, Søren Erik Larsen, Jun Liu, Rasmus Bødker Madsen, Nicolas L. Martin, Martin Molis, Mette Hilleke Mortensen, Alireza Motevalli, Emil Muff, Ingelise Møller, Maria Ondracek, Rasmus Jes Petersen, Lorenzo Pugliese, Albert Rosenkrantz, Peter Sandersen, Raphael J.M. Schneider, Torben O. Sonnenborg, Simon Stisen, Peter Borgen Sørensen, Lærke Thorling, Henrik Tornbjerg, Lars Troldborg, Lars Uldall-Jessen, Denitza Voutchkova, Jens Aamand. 2025. National kvælstofmodel - version 2025. Udvikling af nye kvælstofretentionskort. Metode rapport. De Nationale Geologiske Undersøgelser for Danmark og Grønland. GEUS særudgivelse.*

Fjordbøge, A. S., Broholm, M. M., Mosthaf, K., Janniche, G. S., Binning, P. J., Bjerg, P. L., Skov, B. H., & Kerrn Jespersen, H. (2016): Forureningsundersøgelser i kalkmagasiner: metoder til karakterisering af forureningsfordeling. In ATV - Jord og Grundvand 2016: Abstractsamling (pp. 15-16). ATV Jord og Grundvand

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Hansen, B., Voutchkova, D. D., Sandersen, P. B. E., Kallesøe, A., Thorling, L., Møller, I., Madsen, R. B., Jakobsen, R., Aamand, J., Maurya, P. & Kim, H., 2021. Assessment of complex subsurface redox structures for sustainable development of agriculture and the environment. *Environmental Research Letters*, *16*(2), Article 025007. https://doi.org/10.1088/1748-9326/abda6d

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Smith, M.S., Firestone, M.K., Tiedje, J.M., 1978: The Acetylene Inhibition Method for Short-term Measurements of Soil Denitrification and its evaluation Using Nitrogen-13. Soil Sci. Soc. Am. J. 42:611-615.

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Voutchkova, D., Hansen, B. & Julian Koch, J., 2025: New method for assessing the likelihood of nitrate-containing groundwater in Danish carbonate aquifers. *Appendix in: Anker Lajer Højberg, Hans Thodsen, Christen Duus Børgesen (red.) Anne Hasselholt Andersen, Lærke Therese*

Andersen, Joachim Audet, Eva O. Bach, David Terpager Christiansen, Ditte Asmussen Christiansen, Joel Tirado Conde, Frederik Alexander Falk, Rasmus Rumph Frederiksen, Franca Giannini-Kurina, Jacob Gudbjerg, Birgitte Hansen, Christopher Vincent Henri, Emil Skole Henriksen, Nichlas Hermansen, Carl Christian Hoffmann, Anne-Sophie Høyer, Bo Vangsø Iversen, Rasmus Jakobsen, Margit Styrbæk Jørgensen, Hyojin Kim, Ane Kjeldgaard, Julian Koch, Brian Kronvang, Søren Erik Larsen, Jun Liu, Rasmus Bødker Madsen, Nicolas L. Martin, Martin Molis, Mette Hilleke Mortensen, Alireza Motevalli, Emil Muff, Ingelise Møller, Maria Ondracek, Rasmus Jes Petersen, Lorenzo Pugliese, Albert Rosenkrantz, Peter Sandersen, Raphael J.M. Schneider, Torben O. Sonnenborg, Simon Stisen, Peter Borgen Sørensen, Lærke Thorling, Henrik Tornbjerg, Lars Troldborg, Lars Uldall-Jessen, Denitza Voutchkova, Jens Aamand. 2025. National kvælstofmodel - version 2025. Udvikling af nye kvælstofretentionskort. Metode rapport. De Nationale Geologiske Undersøgelser for Danmark og Grønland. GEUS særudgivelse

Appendices

Appendix 1: Well reports from the existing wells used for water sampling.

Appendix 2: Well reports from the 4 new wells

Appendix 3: Water chemistry of new and existing wells

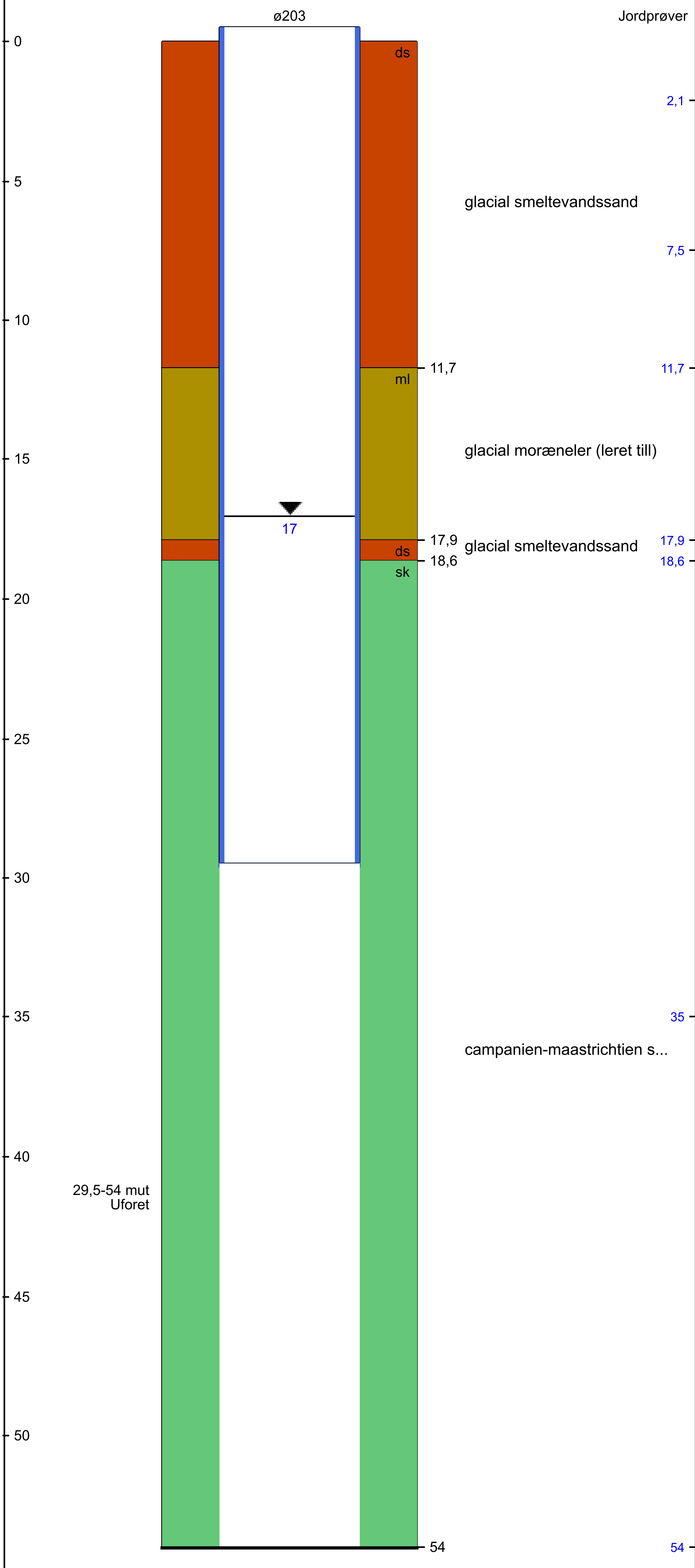
Appendix 4: Gasanalyses Villestrup

Appendix 5. Sediment analyses

Appendix 6: Well panels with results

Appendix 1: Well reports from the existing wells used for water sampling.

Well description from the Jupiterdatabase.



G E U S

DGU-nr: 49.378

Borerapport

Formål	: Vandingsboring
Ejer	
Borested	: Rostrup Damstedgård jan Baks
Placering	: UTM32 557250 6289046
Terrænkote	: 42,4 meter over DVR90
Lokalnummer	
Sagsnummer	
Boredato	: 01-01-1979
Brøndborer	: borearkiv

Boreteknik

Metode	: Tør
Dimension	: 254 mm til 29,5 mut

Stamme 1

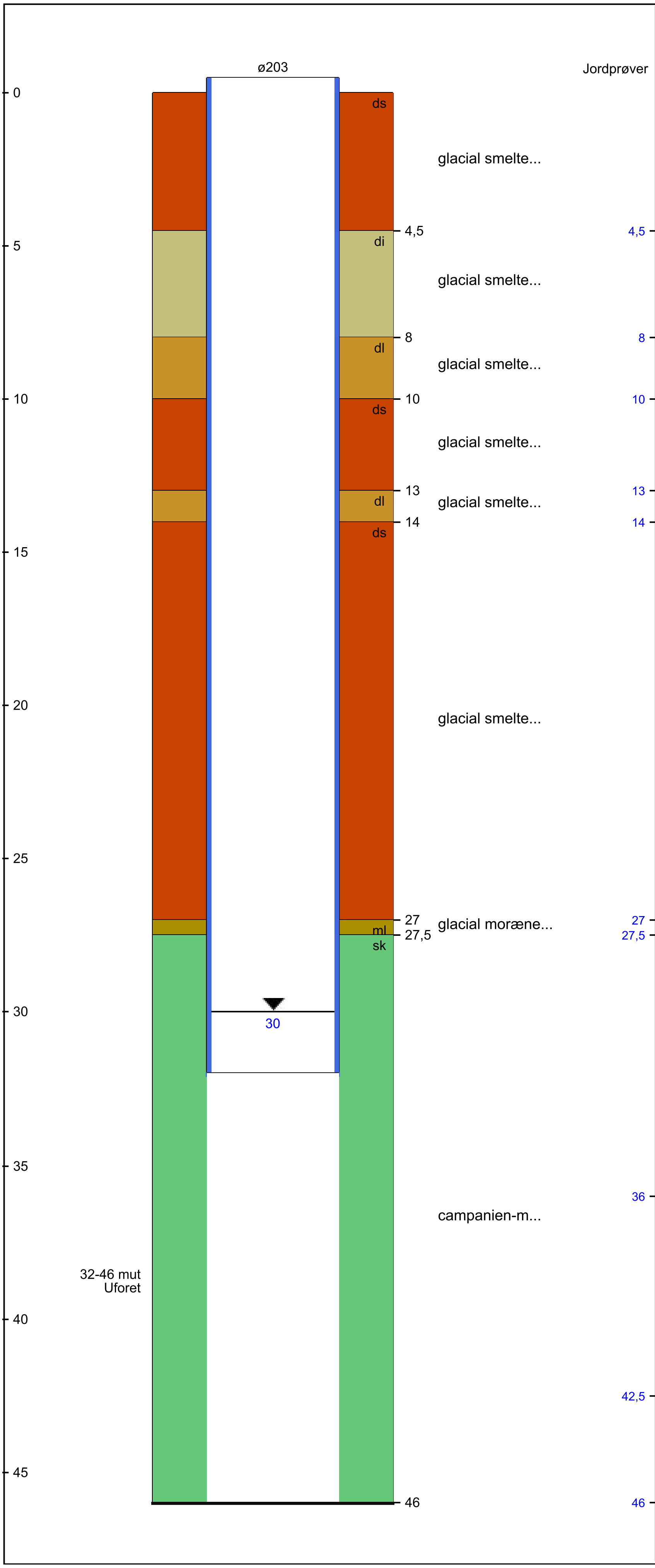
-0,5 - 29,5	: 203 mm
29,5 - 54	: 203 mm Uforet
Vandstand i ro	: 17 mut, 05-11-2009
Sænkning	: 38 m³ / t : 2,8 m

Jordprøver

Jordprøver	: Udprintes ikke

GEUS

Adresse	: Øster Voldgade 10
By	: 1350 København K
Telefon	: 38142000
E-mail	: geus@geus.dk



GEUS

DGU-nr: 49.385

Borerapport

Formål : Vandingsboring
Ejer
Borested : Hadsund Tostrup Hedegaard ...
Placering : UTM32 560740 6285526
Terrænkote : 40 meter over DVR90
Lokalnummer
Sagsnummer
Boredato : 26-05-1980
Brøndborer : borearkiv

Boreteknik

Metode : Tør
Dimension : 203 mm til 32 mut

Stamme 1

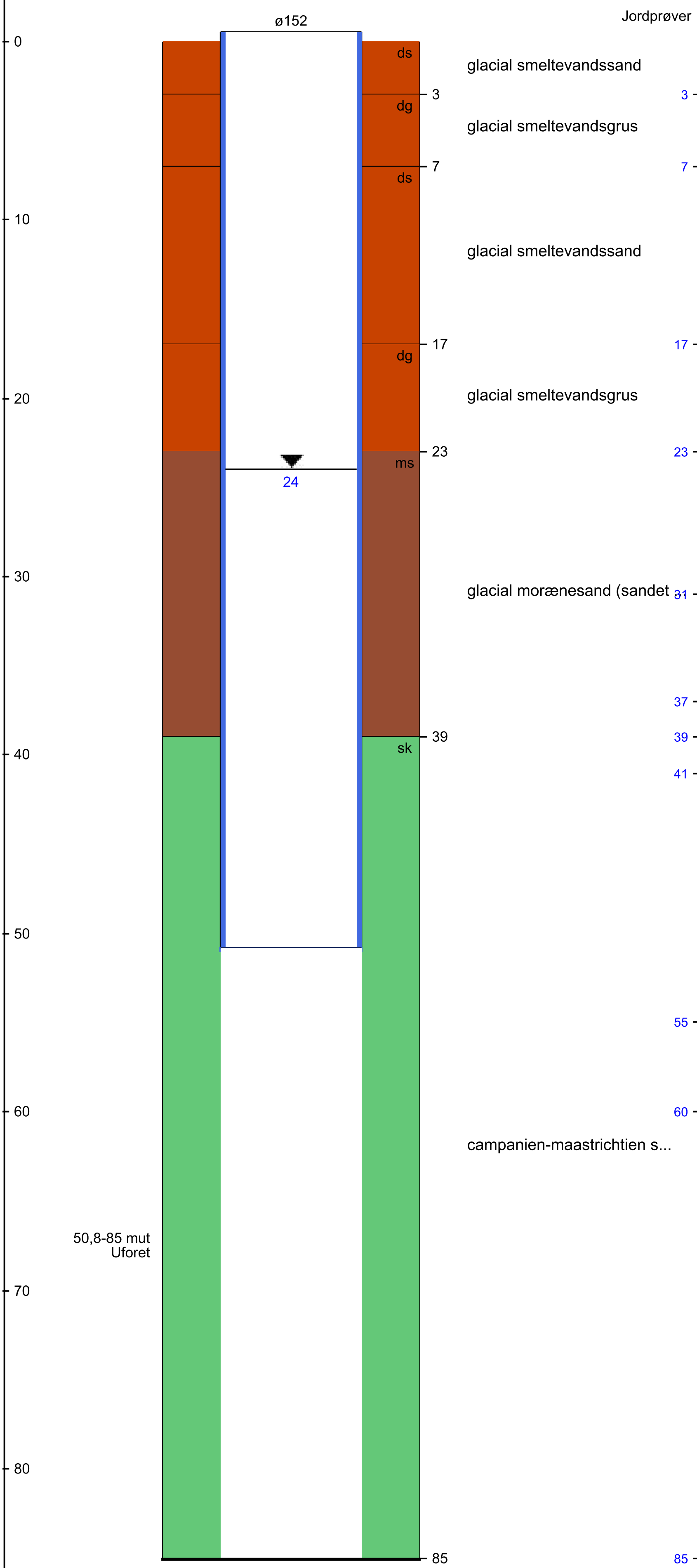
-0,5 - 32 : 203 mm
32 - 46 : 203 mm Uforet
Vandstand i ro : 30 mut, 05-08-1980
Sænkning : 25 m³ / t : 0,6 m

Jordprøver

Jordprøver : Udprintes ikke

GEUS

Adresse : Øster Voldgade 10
By : 1350 København K
Telefon : 38142000
E-mail : geus@geus.dk



G E U S

DGU-nr: 49.386

Borerapport

Formål	: Vandingsboring
Ejer	
Borested	: Arden Rostrup Frembjerg Jen...
Placering	: UTM32 557638 6289660
Terrænkote	: 47,64 meter over DVR90
Lokalnummer	
Sagsnummer	
Boredato	: 17-03-1980
Brøndborer	: borearkiv

Boreteknik

Metode	: Tør
Dimension	: 305 mm til 50,8 mut

Stamme 1

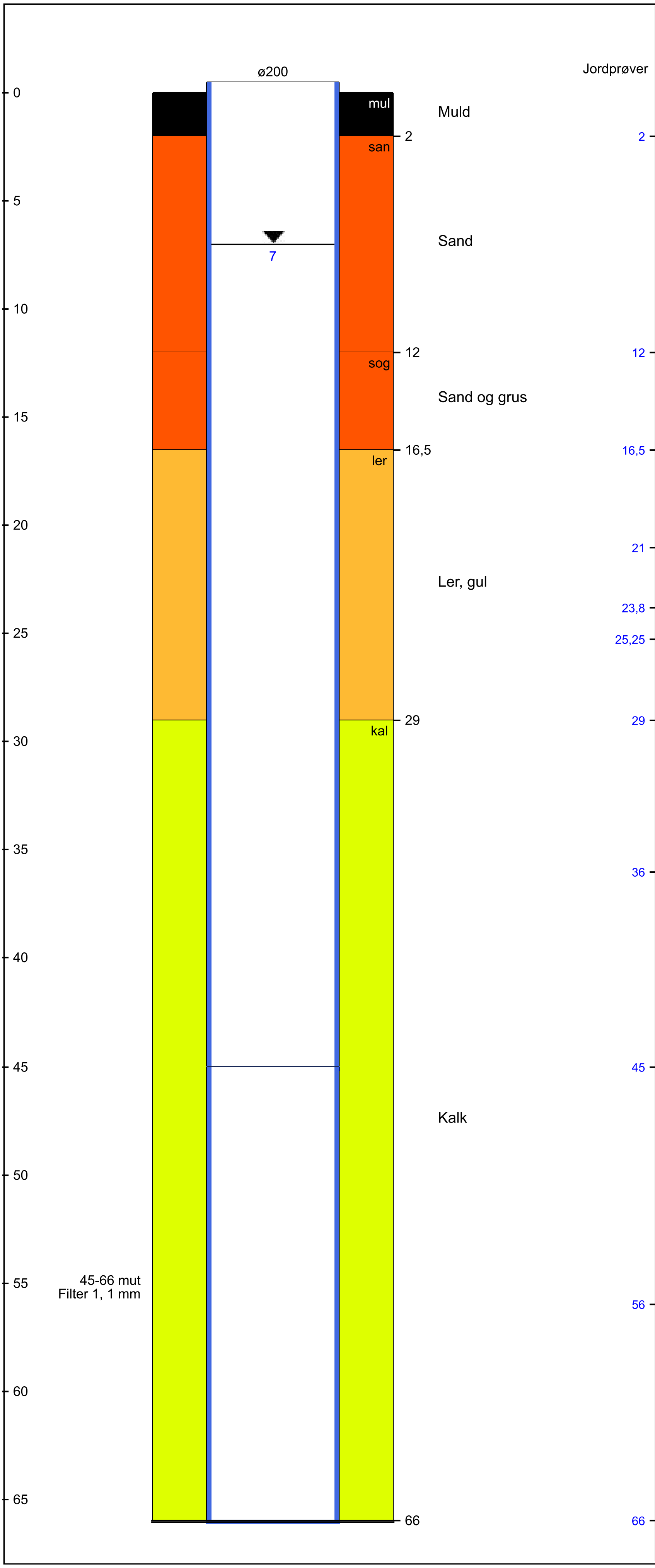
-0,5 - 50,8	: 152 mm
50,8 - 85	: 152 mm Uforet
Vandstand i ro	: 24 mut, 18-06-2009
Sænkning	: 26,6 m³ / t : 6 m

Jordprøver

Jordprøver	: Udprintes ikke

GEUS

Adresse	: Øster Voldgade 10
By	: 1350 København K
Telefon	: 38142000
E-mail	: geus@geus.dk



G E U S

DGU-nr: 49.448

Borerapport

Formål	: Vandværksboring
Ejer	
Borested	: ove vv, Skrænten 5, ove
Placering	: UTM32 559740 6283799
Terrænkote	: 27,7 meter over DVR90
Lokalnummer	
Sagsnummer	
Boredato	: 20-02-1983
Brøndborer	: borearkiv

Boreteknik

Metode	: Tør
Dimension	: 250 mm til 45 mut
	: 240 mm til 45 mut

Stamme 1

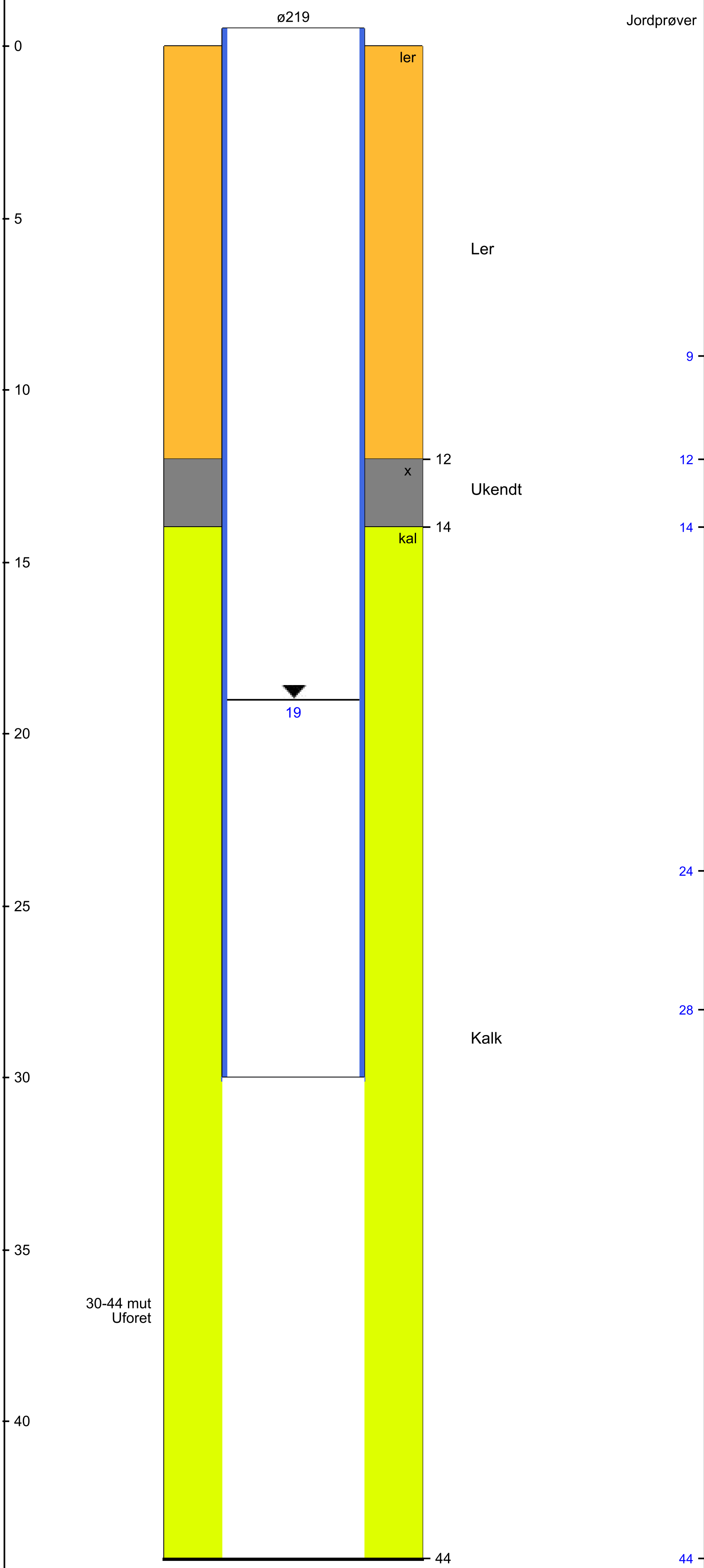
-0,5 - 45	: 200 mm PVC
45 - 66	: 200 mm PVC
Vandstand i ro	: 7 mut, 10-11-2009
Sænkning	: 24 m³ / t : 2,9 m

Jordprøver

Jordprøver	: Udprintes ikke

GEUS

Adresse	: Øster Voldgade 10
By	: 1350 København K
Telefon	: 38142000
E-mail	: geus@geus.dk



G E U S

DGU-nr: 49.594

Borerapport

Formål	: Vandingsboring
Ejer	
Boretsted	: Hedegårdsvej 5, Arden
Placering	: UTM32 558914 6286849
Terrænkote	: 31 meter over DVR90
Lokalnummer	
Sagsnummer	
Boredato	: 18-05-1996
Brøndborer	: borearkiv

Boreteknik

Metode	: Tør
Dimension	: 219 mm til 30 mut

Stamme 1

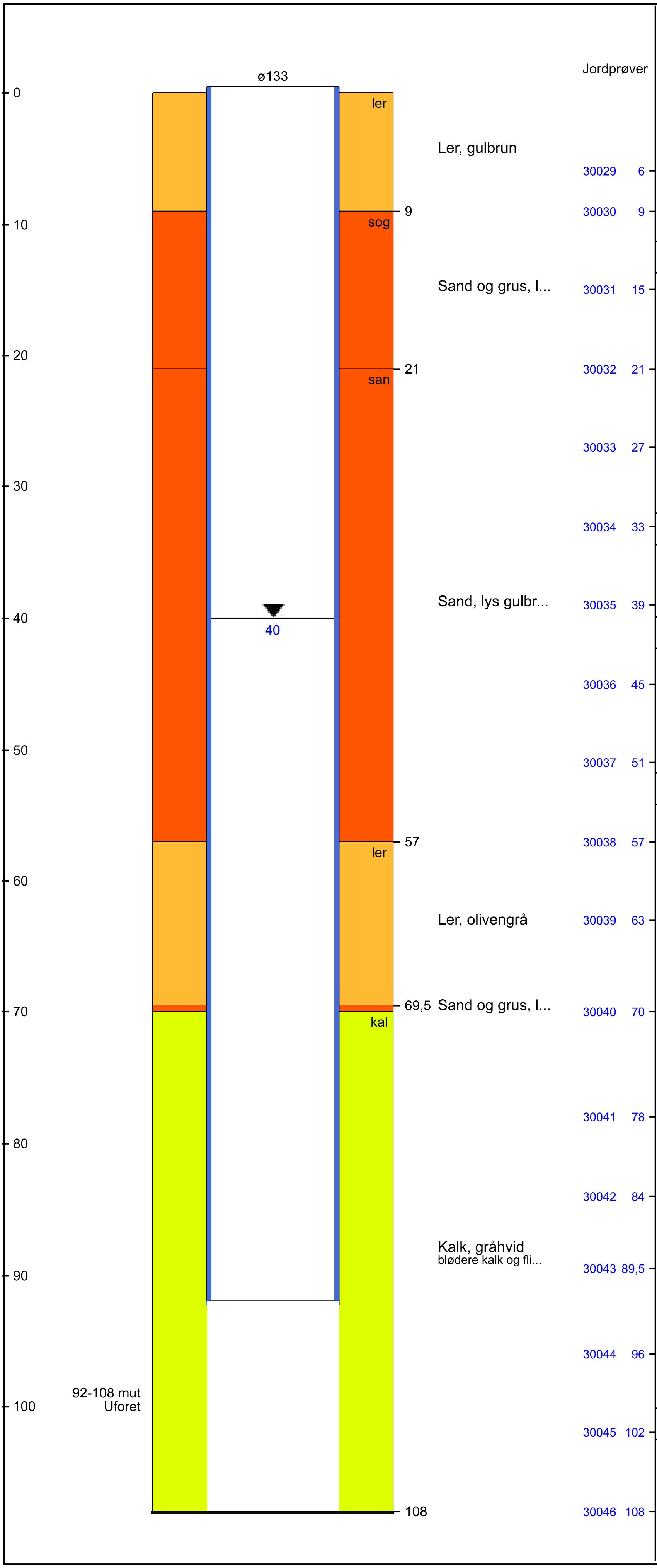
-0,5 - 30	: 219 mm
30 - 44	: 219 mm Uforet
Vandstand i ro	: 19 mut, 01-06-2002
Sænkning	: 30 m³ / t : 3,8 m

Jordprøver

Jordprøver	: Udprintes ikke

GEUS

Adresse	: Øster Voldgade 10
By	: 1350 København K
Telefon	: 38142000
E-mail	: geus@geus.dk



G E U S

DGU-nr: 49.965

Borerapport

Formål : Privat husholdningsboring
Ejer
Borested : Rostrupvej 10
Placering : UTM32 554503 6285205
Terrænkote : 86,01 meter over DVR90
Lokalnummer
Sagsnummer : Rostruvej 10
Boredato : 29-06-2004
Brøndborer : borearkiv

Boreteknik

Metode : Rotaryboring
Dimension : 250 mm til 108 mut

Stamme 1

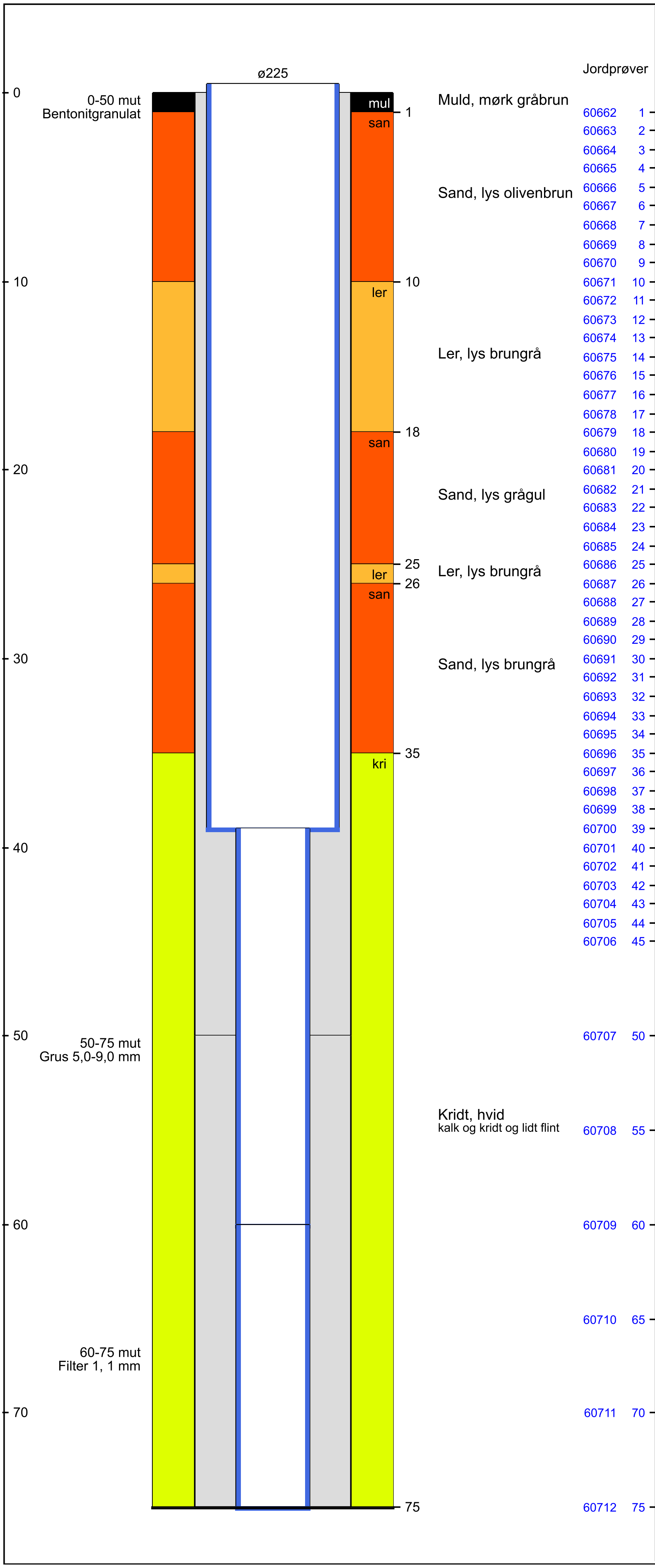
-0,5 - 92 : 133 mm Jern/rustfrit
92 - 108 : 133 mm Uforet
Vandstand i ro : 40 mut, 04-11-2009
Sænkning : 5,5 m³ / t : 0,71 m

Jordprøver

Jordprøver : Udprintes ikke

GEUS

Adresse : Øster Voldgade 10
By : 1350 København K
Telefon : 38142000
E-mail : geus@geus.dk



G E U S

DGU-nr: 49.1002

Borerapport

Formål	: Privat husholdningsboring
Ejer	
Boresteds	: Storemosevej 6
Placering	: UTM32 558671 6289112
Terrænkote	: 17,75 meter over DVR90
Lokalnummer	
Sagsnummer	
Boredato	: 02-02-2006
Brøndborer	: borearkiv

Boreteknik

Metode	: Lufthæve
Dimension	: 200 mm til 75 mut
	: 400 mm til 75 mut

Stamme 1

-0,5 - 39	: 225 / 8 mm PVC , Limet muffe
39 - 60	: 125 / 8 mm PVC , Gevind
60 - 75	: 125 / 8 mm PVC , Gevind
Vandstand i ro	

Jordprøver

Jordprøver	: Udprintes ikke

GEUS

Adresse	: Øster Voldgade 10
By	: 1350 København K
Telefon	: 38142000
E-mail	: geus@geus.dk

Appendix 2: Well reports from the 4 new wells

De Nationale Geologiske Undersøgelser for Danmark og Grønland

BORERAPPORT

DGU arkivnr: 49. 2527

Borested : Egelundsvej 20
9510 Arden

Kommune : Mariagerfjord
Region : Nordjylland

Boringsdato : 2/5 2023
Boringsdybde : 15,56 meter
Terrænkote : 22,3 meter o. DNN

Brøndborer : Palle Ejlskov
MOB-nr :
BB-journr :
BB-bornr : V1

Prøver
- modtaget : 4/5 2023 **antal** : 25
- beskrevet : 30/5 2023 **af** : HJG
- antal gemt : 0

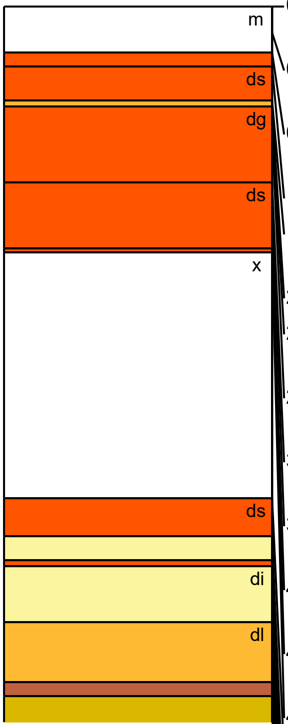
Formål : Undersøg./videnskab
Anvendelse :
Boremetode :

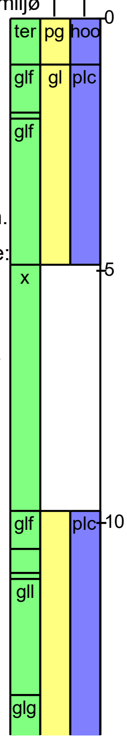
Kortblad : 1316IIINV
UTM-zone : 32
UTM-koord. : 557672, 6288551

Datum : WGS84
Koordinatkilde : Brøndborer
Koordinatmetode : Luftfoto

Kronostratigrafi
Klimastratigrafi
Dannelsesmiljø

meter u.t.





0 **MULD**, sandet, indh. af humøs substans, mørk brun 10YR 2/2, kalkfri. (muld). Prøve udtaget ved 25 m.

0,5 **MULD**, sandet, gruset, indh. af humøs substans, mørk gråbrun 10YR 3/2, kalkfri. (muld). Prøve udtaget ved .7 m.

0,9 **GRUS**, usorteret, sandet, mørk gråbrun 10YR 4/3, kalkfri, "smeltevandsgrus". Prøve udtaget ved 1.05 m.

1,2 **SAND**, fint og mellem, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 1.8 m.

1,85 **LER**, ret fedt, lys brunsort 2.5Y 6/2, kalkfri, "smeltevandsler". Prøve udtaget ved 1.9 m. Note: Med rødbrune jernudfældningspletter.

2 **GRUS**, sandet, lys gråbrun 10YR 6/3, kalkfri, "smeltevandsgrus". Prøve udtaget ved 2.1 m.

2,3 **SAND OG GRUS**, mellem og usorteret, gulbrun 10YR 5/4, kalkfri, "smeltevandssand og grus". Prøve udtaget ved 2.4 m.

2,44 **SAND OG GRUS**, mellem og usorteret, gulbrun 10YR 5/4, kalkfri, "smeltevandssand og grus". Prøve udtaget ved 3.6 m.

3,5 **SAND**, mest mellem, lys gulbrun 2.5Y 6/3, kalkfri, "smeltevandssand". Prøve udtaget ved 3.6 m.

3,66 **SAND**, mest mellem, lys brungrå 10YR 6/2, kalkfri, "smeltevandssand". Prøve udtaget ved 4.4 m.

4,5 **SAND**, mellem og groft, gruset, lys brungrå 10YR 6/2, kalkfri, "smeltevandssand". Prøve udtaget ved 4.7 m.

4,8 **GRUS**, usorteret, sandet, lys brungrå 10YR 6/2, kalkfri, "smeltevandsgrus". Prøve udtaget ved 4.85 m.

4,88 (ukendt lag, oplysninger mangler).

9,76 **SAND**, mest mellem, lys brungrå 10YR 6/2, kalkfri, "smeltevandssand". Prøve udtaget ved 10.15 m. Note: Grænse usikker.

10,5 **SILT**, leret, grå 2.5Y 6/1, kalkholdig, "smeltevandssilt". Prøve udtaget ved 10.95 m.

10,98 **SAND**, fint og mellem, lys brungrå 10YR 6/2, stærkt kalkholdig, "smeltevandssand". Prøve udtaget ved 11.05 m.

11,1 **SILT**, leret, lys grå 10YR 7/1, stærkt kalkholdig, "smeltevandssilt". Prøve udtaget ved 11.65 m.

11,7 **SILT**, svagt leret, grå 10YR 6/1, stærkt kalkholdig, "smeltevandssilt". Prøve udtaget ved 12.1 m.

12,2 **LER**, stærkt siltet, lys grå 10YR 7/1, stærkt kalkholdig, "smeltevandsler". Prøve udtaget ved 12.45 m.

12,7 **LER**, stærkt siltet, lys grå 10YR 7/1, stærkt kalkholdig, "smeltevandsler". Prøve udtaget ved 12.9 m.

13,2 **LER**, stærkt siltet, lys grå 10YR 7/1, stærkt kalkholdig, "smeltevandsler". Prøve udtaget ved 13.4 m.

13,42 **SAND**, leret, siltet, gruset, grå 10YR 6/1, indh.af kalkklaster, stærkt kalkholdig, "morænesand". Prøve udtaget ved 13.6 m.

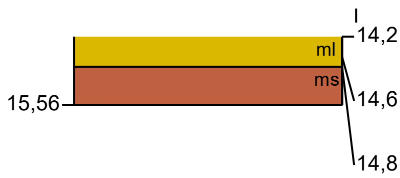
13,7 **LER**, siltet, stærkt sandet, gruset, grå 10YR 6/1, indh.af kalkklaster, stærkt kalkholdig, "moræneler". Prøve udtaget ved 13.9 m.

fortsættes..

BORERAPPORT

DGU arkivnr: 49. 2527

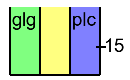
meter u.t.



14,2 **LER**, siltet, sandet, gruset, grå 10YR 6/1, svagt indh.af kalkklaster, stærkt kalkholdig, "moræneler". Prøve udtaget ved 14.45 m.

14,6 **LER**, siltet, sandet, gruset, grå 10YR 6/1, svagt indh.af kalkklaster, stærkt kalkholdig, "moræneler". Prøve udtaget ved 14.7 m.

14,8 **SAND**, svagt leret, siltet, svagt gruset, grå 10YR 5/1, stærkt kalkholdig, "morænesand". Prøve udtaget ved 15.55 m.



Aflejringsmiljø - Alder (klima-, krono-, litho-, biostratigrafi)

meter u.t.			
0	-	0,9	terrigen - postglacial - holocæn
0,9	-	1,85	glaciofluvial - glacial - pleistocæn
1,85	-	2	glaciolakustrin - glacial - pleistocæn
2	-	4,88	glaciofluvial - glacial - pleistocæn
4,88	-	9,76	mangler
9,76	-	10,5	glaciofluvial - - pleistocæn
10,5	-	10,98	glaciolakustrin - - pleistocæn
10,98	-	11,1	glaciofluvial - - pleistocæn
11,1	-	13,42	glaciolakustrin - - pleistocæn
13,42	-	15,56	glacigen - - pleistocæn

BORERAPPORT

DGU arkivnr: 49. 2528

Borested : Egelundsvej 20
9510 Arden

Kommune : Mariagerfjord
Region : Nordjylland

Boringsdato : 1/5 2023
Boringsdybde : 12,2 meter
Terrænkote : 32,1 meter o. DNN

Brøndborer : Palle Ejlskov
MOB-nr :
BB-journr :
BB-bornr : V2

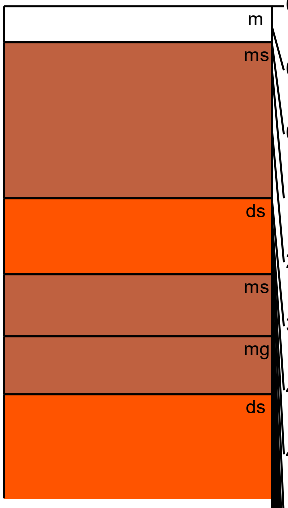
Prøver
- modtaget : 4/5 2023 **antal** : 25
- beskrevet : 26/5 2023 **af** : HJG
- antal gemt : 0

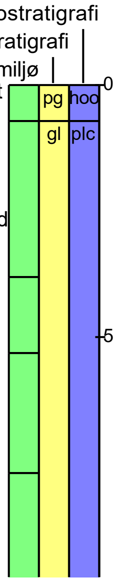
Formål : Undersøg./videnskab
Anvendelse :
Boremetode :

Kortblad : 1316IIINV
UTM-zone : 32
UTM-koord. : 557652, 6288716

Datum : WGS84
Koordinatkilde : Brøndborer
Koordinatmetode : Luftfoto

meter u.t.





0 **MULD**, sandet, svagt gruset, indh. af planterester, sort 10YR 2/1, kalkfri. (muld). Prøve udtaget ved .2 m.

0,4 **MULD**, sandet, svagt gruset, indh. af planterester, mørk brun 10YR 2/2, kalkfri. (muld). Prøve udtaget ved .6 m.

0,7 **SAND**, svagt siltet, svagt gruset, gulbrun 10YR 5/4, kalkfri, "morænesand". Prøve udtaget ved 1 m.

1,22 **SAND**, svagt siltet, gruset, gulbrun 10YR 5/4, kalkfri, "morænesand". Prøve udtaget ved 2.2 m.

2,44 **SAND**, svagt siltet, gruset, mørk gulbrun 10YR 4/4, kalkfri, "morænesand". Prøve udtaget ved 3.6 m.

3,8 **SAND**, mest mellem, svagt gruset, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand". Prøve udtaget ved 4.05 m.

4,15 **SAND**, mest mellem, svagt gruset, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand". Prøve udtaget ved 4.25 m.

4,35 **SAND**, mest mellem, svagt gruset, lys gråbrun 10YR 6/3, kalkfri, "smeltevandssand". Prøve udtaget ved 4.45 m.

4,65 **SAND**, fint og mellem, gruset, lys gråbrun 10YR 6/3, kalkholdig, "smeltevandssand". Prøve udtaget ved 4.85 m.

5,3 **SAND**, svagt siltet, svagt gruset, brun 10YR 5/3, kalkholdig, "morænesand". Prøve udtaget ved 5.35 m.

5,5 **SAND**, svagt leret, siltet, svagt gruset, brun 10YR 5/3, kalkholdig, "morænesand". Prøve udtaget ved 5.7 m.

5,8 **SAND**, svagt leret, siltet, svagt gruset, brun 10YR 5/3, kalkholdig, "morænesand". Prøve udtaget ved 6 m.

6,1 **SAND**, mest mellem, svagt gruset, gråbrun 10YR 5/2, kalkholdig, "morænesand". Prøve udtaget ved 6.5 m.

6,55 **GRUS**, usorteret, svagt siltet, sandet, svagt stenet, gråbrun 10YR 5/2, kalkholdig, "morænegrus". Prøve udtaget ved 6.8 m.

7 **GRUS**, usorteret, svagt siltet, sandet, svagt stenet, gråbrun 10YR 5/2, kalkholdig, "morænegrus". Prøve udtaget ved 7.25 m.

7,7 **SAND**, fint og mellem, lys gråbrun 10YR 6/3, svagt kalkholdig, "smeltevandssand". Prøve udtaget ved 7.8 m.

8,25 **SAND**, mest mellem, svagt gruset, lys gråbrun 10YR 6/3, svagt kalkholdig, "smeltevandssand". Prøve udtaget ved 8.3 m.

8,4 **SAND**, fint og mellem, lys gråbrun 10YR 6/3, svagt kalkholdig, "smeltevandssand". Prøve udtaget ved 8.54 m.

8,85 **SAND**, mest mellem, svagt gruset, lys brungrå 10YR 6/2, kalkfri, "smeltevandssand". Prøve udtaget ved 9 m.

9,2 **SAND**, mest mellem, lys brungrå 10YR 6/2, svagt kalkholdig, "smeltevandssand". Prøve udtaget ved 9.4 m.

9,5 **SAND**, fint og mellem, lys brungrå 10YR 6/2, kalkholdig, "smeltevandssand". Prøve udtaget ved 9.65 m.

fortsættes..

BORERAPPORT

DGU arkivnr: 49. 2528

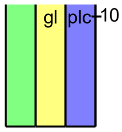
meter u.t.

9,76 **SAND**, fint og mellem, lys brungrå 10YR 6/2, svagt kalkholdig, "smeltevandssand". Prøve udtaget ved 10.2 m.

10,7 **SAND**, mest mellem, lys brungrå 10YR 6/2, svagt kalkholdig, "smeltevandssand". Prøve udtaget ved 10.9 m.

10,98 **SAND**, mest mellem, svagt gruset, lys brungrå 10YR 6/2, kalkholdig, "smeltevandssand". Prøve udtaget ved 11.2 m.

11,65 **SAND**, mest fint, lys gråbrun 10YR 6/3, kalkholdig, "smeltevandssand". Prøve udtaget ved 12.1 m.



Aflejringsmiljø - Alder (klima-, krono-, litho-, biostratigrafi)

meter u.t.			
0	-	0,7	/terrigen - postglacial - holocæn
0,7	-	3,8	/glacigen - glacial - pleistocæn
3,8	-	5,3	/glaciofluvial - glacial - pleistocæn
5,3	-	7,7	/glacigen - glacial - pleistocæn
7,7	-	12,2	/glaciofluvial - glacial - pleistocæn

BORERAPPORT

DGU arkivnr: 49. 2529

Borested : Egelundsvej 20
9510 Arden

Kommune : Mariagerfjord
Region : Nordjylland

Boringsdato : 1/5 2023 **Boringsdybde** : 12,2 meter **Terrænkote** : 28,16 meter o. DNN

Brøndborer : Palle Ejlskov
MOB-nr :
BB-journr :
BB-bornr : V3

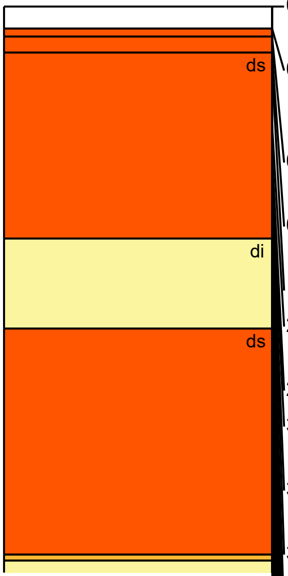
Prøver
- modtaget : 4/5 2023 **antal** : 25
- beskrevet : 25/5 2023 **af** : HJG
- antal gemt : 0

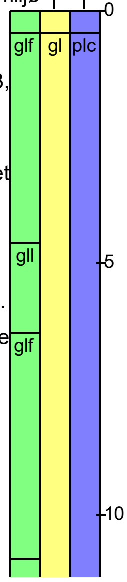
Formål : Undersøg./videnskab
Anvendelse :
Boremetode :

Kortblad : 1316IIINV
UTM-zone : 32
UTM-koord. : 557585, 6288562

Datum : WGS84
Koordinatkilde : Brøndborer
Koordinatmetode : Luftfoto

meter u.t.





0 **MULD**, sandet, indh. af planterester, mørk brun 10YR 2/2, kalkfri. (muld). Prøve udtaget ved .3 m.

0,45 **SAND**, fint og mellem, svagt muld-holdig, svagt indh. af planterester, mørk gråbrun 10YR 3/3, kalkfri, "smeltevandssand", Udført: sigteanalyse. Prøve udtaget ved .5 m. Note: Bw - horisont.

0,6 **SAND**, svagt siltet, svagt gruset, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved .7 m.

0,9 **SAND**, mest mellem, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand", Udført: sigteanalyse. Prøve udtaget ved 1 m. Note: Fint mellemsand, 1/3 fint sand.

1,22 **SAND**, mest fint, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand". Prøve udtaget ved 1.8 m.

2,35 **SAND**, mest groft, gruset, svagt stenet, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 2.44 m.

2,9 **SAND**, mest fint, lys gråbrun 10YR 7/4, kalkfri, "smeltevandssand". Prøve udtaget ved 3.1 m.

3,4 **SAND**, mellem og groft, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand", Udført: sigteanalyse. Prøve udtaget ved 3.5 m.

3,66 **SAND**, mellem og groft, svagt gruset, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand". Prøve udtaget ved 4.1 m.

3,8 **SAND**, mest mellem, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand". Prøve udtaget ved 4.5 m.

4,6 **SILT**, svagt leret, lys gulbrun 2.5Y 6/4, kalkholdig, "smeltevandssilt". Prøve udtaget ved 4.7 m.

4,88 **SILT**, svagt leret, lys gulbrun 2.5Y 6/4, kalkholdig, "smeltevandssilt". Prøve udtaget ved 4.9 m.

5,3 **SILT**, leret, lys gulbrun 2.5Y 6/3, kalkholdig, "smeltevandssilt". Prøve udtaget ved 5.6 m.

6 **SILT**, leret, lys gulbrun 2.5Y 6/3, kalkholdig, "smeltevandssilt". Prøve udtaget ved 6 m. Note: USIKKER GRÆNSE.

6,4 **SAND**, mest mellem, brun 10YR 5/3, kalkfri, "smeltevandssand". Prøve udtaget ved 6.6 m. Note: Vandmættet.

6,8 **SAND**, mest mellem, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand". Prøve udtaget ved 7.3 m. Note: Groft mellemsand.

7,32 **SAND**, mest mellem, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 7.8 m. Note: Vandmættet.

8 **SAND**, mest mellem, svagt gruset, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand". Prøve udtaget ved 8.5 m.

8,54 **SAND**, mest mellem, svagt leret, svagt siltet, lys brungrå 10YR 6/2, kalkholdig, "smeltevandssand". Prøve udtaget ved 9.2 m. Note: Vandmættet.

9,6 **SAND**, mest fint, grå 10YR 6/1, kalkholdig, "smeltevandssand". Prøve udtaget ved 9.7 m.

9,76 **SAND**, mest fint, grå 10YR 5/1, kalkholdig, "smeltevandssand". Prøve udtaget ved 10.1 m. Note: Vandmættet.

10,9 **LER**, siltet, lys gulbrun 2.5Y 6/3, stærkt kalkholdig, "smeltevandsler". Prøve udtaget ved 10.9 m.

11 **SILT**, stærkt leret, lys gulbrun 2.5Y 6/3, stærkt kalkholdig, "smeltevandssilt". Prøve udtaget ved 11.05 m.

fortsættes..

BORERAPPORT

DGU arkivnr: 49. 2529

meter u.t.

11,25 **SILT**, svagt leret, lys brunsort 2.5Y 6/2, stærkt kalkholdig, "smeltevandssilt". Prøve udtaget ved 11.45 m. gll gl plc

12 **SILT**, leret, slirer af sand, lys brunsort 2.5Y 6/2, stærkt kalkholdig, "smeltevandssilt". Prøve udtaget ved 12.1 m. Note: Finsandede slirer.

Aflejringsmiljø - Alder (klima-, krono-, litho-, biostratigrafi)

meter u.t.	
0 - 0,45	terrigen - postglacial - holocæn
0,45 - 4,6	glaciofluvial - glacial - pleistocæn
4,6 - 6,4	glaciolakustrin - glacial - pleistocæn
6,4 - 10,9	glaciofluvial - glacial - pleistocæn
10,9 - 12,2	glaciolakustrin - glacial - pleistocæn

BORERAPPORT

DGU arkivnr: 49. 2530

Borested : Egelundsvej 20
9510 Arden

Kommune : Mariagerfjord
Region : Nordjylland

Boringsdato : 4/5 2023
Boringsdybde : 12,2 meter
Terrænkote : 56,9 meter o. DNN

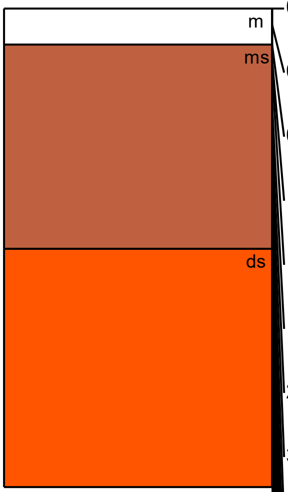
Brøndborer : Palle Ejlskov
MOB-nr :
BB-journr :
BB-bornr : V4

Prøver
- modtaget : 4/5 2023 **antal** : 26
- beskrevet : 31/5 2023 **af** : HJG
- antal gemt : 0

Formål : Undersøg./videnskab
Anvendelse :
Boremetode :

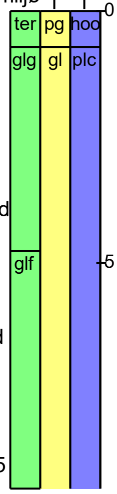
Kortblad : 1316IIINV
UTM-zone : 32
UTM-koord. : 557089, 6287404

Datum : WGS84
Koordinatkilde : Brøndborer
Koordinatmetode : Luftfoto



meter u.t.

Kronostratigrafi
Klimastratigrafi
Dannelsesmiljø



0 **MULD**, svagt siltet, sandet, indh. af humøs substans, sort 10YR 2/1, kalkfri. (muld). Prøve udtaget ved .15 m.

0,3 **MULD**, siltet, svagt sandet, indh. af humøs substans, mørk brun 10YR 2/2, kalkfri. (muld). Prøve udtaget ved .5 m.

0,7 **SAND**, svagt leret, svagt siltet, lys gråbrun 10YR 6/3, kalkfri, "morænesand". Prøve udtaget ved .9 m.

1 **SAND**, svagt leret, svagt siltet, lys gråbrun 10YR 6/3, kalkfri, "morænesand". Prøve udtaget ved 1.2 m.

1,22 **SAND**, svagt leret, svagt siltet, svagt gruset, gulbrun 10YR 5/4, kalkfri, "morænesand". Prøve udtaget ved 1.6 m.

1,9 **SAND**, leret, siltet, svagt gruset, gulbrun 10YR 5/4, kalkfri, "morænesand". Prøve udtaget ved 2.4 m.

2,44 **SAND**, leret, siltet, svagt gruset, brun 10YR 5/3, kalkfri, "morænesand". Prøve udtaget ved 2.7 m.

3 **SAND**, leret, siltet, svagt gruset, brun 10YR 5/3, kalkfri, "morænesand". Prøve udtaget ved 3.55 m.

3,66 **SAND**, leret, siltet, svagt gruset, brun 10YR 5/3, kalkfri, "morænesand". Prøve udtaget ved 3.8 m.

4,2 **SAND**, leret, siltet, svagt gruset, brun 10YR 5/3, kalkfri, "morænesand". Prøve udtaget ved 4.55 m.

4,75 **SAND**, mest mellem, svagt gruset, flint-holdig, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 4.8 m.

4,88 **SAND**, mest mellem, svagt gruset, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 5.1 m.

5,5 **SAND**, mest mellem, svagt gruset, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 5.8 m.

5,9 **SAND**, mest mellem, svagt gruset, lys gulbrun 10YR 6/4, kalkfri, "smeltevandssand". Prøve udtaget ved 6 m.

6,1 **SAND**, mest mellem, svagt gruset, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 6.5 m.

6,8 **SAND**, mest mellem, svagt gruset, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 7.25 m.

7,32 **SAND**, mest mellem, svagt gruset, gulbrun 10YR 5/4, kalkfri, "smeltevandssand". Prøve udtaget ved 7.7 m.

8 **SAND**, mest mellem, svagt gruset, lys gråbrun 10YR 6/3, kalkfri, "smeltevandssand". Prøve udtaget ved 8.25 m.

8,3 **SAND**, mest mellem, gruset, lys gråbrun 10YR 6/3, kalkfri, "smeltevandssand", Udført: sigteanalyse. Prøve udtaget ved 8.5 m. Note: Fint mellemsand, 1/3 fint sand.

8,54 **SAND**, mest mellem, gruset, lys gråbrun 10YR 6/3, stærkt kalkholdig, "smeltevandssand". Prøve udtaget ved 8.8 m.

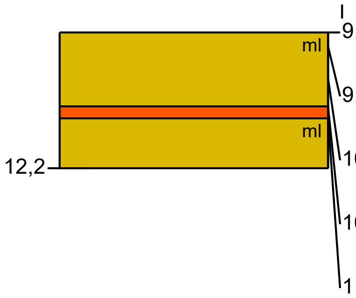
9 **SAND**, mest mellem, gruset, lys brungrå 10YR 6/2, svagt indh.af kalkklaster, stærkt kalkholdig, "smeltevandssand". Prøve udtaget ved 9.2 m. Note: Fint mellemsand.

fortsættes..

BORERAPPORT

DGU arkivnr: 49. 2530

meter u.t.



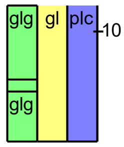
9,5 **LER**, siltet, stærkt sandet, svagt gruset, lys gråbrun 10YR 6/3, svagt indh.af kalkklaster, stærkt kalkholdig, "moræneler". Prøve udtaget ved 9.65 m.

9,76 **LER**, siltet, stærkt sandet, svagt gruset, lys brungrå 10YR 6/2, svagt indh.af kalkklaster, stærkt kalkholdig, "moræneler". Prøve udtaget ved 10 m.

10,4 **LER**, siltet, sandet, svagt gruset, lys brungrå 10YR 6/2, svagt indh.af kalkklaster, stærkt kalkholdig, "moræneler". Prøve udtaget ved 10.9 m.

10,98 **SAND**, mest mellem, svagt gruset, lys gråbrun 10YR 6/3, kalkholdig, "smeltevandssand". Prøve udtaget ved 11 m.

11,2 **LER**, siltet, sandet, svagt gruset, lys gråbrun 10YR 6/3, svagt indh.af kalkklaster, stærkt kalkholdig, "moræneler". Prøve udtaget ved 12.1 m.



Aflejringsmiljø - Alder (klima-, krono-, litho-, biostratigrafi)

meter u.t.	
0 - 0,7	terrigen - postglacial - holocæn
0,7 - 4,75	glacigen - glacial - pleistocæn
4,75 - 9,5	glaciofluvial - glacial - pleistocæn
9,5 - 10,98	glacigen - glacial - pleistocæn
10,98 - 11,2	glaciofluvial - glacial - pleistocæn
11,2 - 12,2	glacigen - glacial - pleistocæn

Appendix 3: Water chemistry of new and existing wells

Tabel 1. Water Chemistry of existing wells Villestrup 2023. continues in Tabel 2. Note Danish numbers.

		depth	Temp	O2	pH	EC	Fe(field)	NO3(field)	F	Cl	NO3	PO4	SO4	HCO3	NH4	DOC	Na	Mg	K	Ca	Mn	Fe
Date	DGUnr.	mbs		mg/l		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
25-04-2023	**49.378**	30,5							0,056	26,2	45,5	<0,005	14,5		0,244	1,87	11,5	6,2	3,0	66	0,093	0,20
25-04-2023	**49.378**	38	10,1	10,1	7,07	517	0	46,9	0,049	25,6	64,9	0,026	19,2	2,93	0,021	3,19	10,9	6,3	1,1	75	0,010	0,23
25-04-2023	**49.378**	45,5	10,1	10,4	7,58	501	0	50,0	0,052	25,7	64,6	0,014	18,4	2,88	0,010	2,17	11,2	6,2	1,1	76	0,006	0,24
25-04-2023	**49.378**	53	11,8	10,3	7,22	496	0	45,2	0,053	25,7	64,6	0,016	18,2	2,80	0,008	2,39	11,0	6,1	1,1	75	0,006	0,28
25-04-2023	**49.1002**	61	10,7	7,27	7,48	1384	0	0	0,830	280	1,32	<0,005	94,5	3,97	0,204	1,91	n.d.	31,5	3,2	71	0,003	0,14
25-04-2023	**49.1002**	73	10,9	7,53	7,68	3260	0	0	1,33	874	1,30	<0,005	135	4,68	0,678	2,13	n.d.	52,6	6,7	95	0,004	0,19
26-04-2023	**49.448**	47	12,5	9	7,02	396	0	0	0,179	22,9	3,88	<0,005	35,7	2,45	<0,005	1,67	7,8	4,2	1,5	55	0,010	0,13
26-04-2023	**49.448**	59	11,1	9,13	7,43	387	0,01	0	0,175	22,7	4,16	<0,005	37,4		<0,005	2,83	7,9	4,4	1,5	57	0,013	0,12
26-04-2023	**49.448**	65	10,8	9,57	7,16	384	0	0	0,207	22,2	3,68	<0,005	37,6	2,69	<0,005	2,71	7,9	4,5	1,5	57	0,021	0,13
26-04-2023	**49.385**	33	6,1	10,3	7,7	480	0	14,2	0,061	24,3	29,7	<0,005	47,9	2,83	<0,005	2,57	9,7	6,6	1,2	68	0,011	0,17
26-04-2023	**49.385**	37	4,3	9,1	7,78	478	0	19,0	0,058	24,3	30,5	<0,005	47,5	2,79	<0,005	3,01	10,1	7,0	1,2	73	0,010	0,19
26-04-2023	**49.385**	41	4,7	10,4	7,84	475	0	19,5	0,056	24,1	31,1	<0,005	47,1	2,80	<0,005	2,59	9,7	6,7	1,2	70	0,012	1,19
26-04-2023	**49.385**	45	3,1	10,7	7,99	471	0,06	50,5	0,058	24,1	30,2	<0,005	47,1	2,86	<0,005	2,50	9,8	6,7	1,2	70	0,015	0,17
27-04-2023	**49.965**	93		8,05		361			0,040	22,5	38,2	<0,005	28,4	1,64	<0,005	6,51	8,6	2,0	0,8	51	0,145	0,11
27-04-2023	**49.965**	97,6	15,9	10,4	7,64	375	0	31,0	0,076	23,0	41,3	<0,005	29,5	1,59	<0,005	2,39	8,8	2,1	0,9	54	0,054	0,11
27-04-2023	**49.965**	102,2	17	9,9	7,71	366	0,04	30,6	0,071	22,9	42,1	<0,005	29,1	1,61	<0,005	1,94	8,4	2,0	0,8	53	0,022	0,10
27-04-2023	**49.965**	106,8	14,5	9,3	7,8	363	0,03	27,9	0,069	22,9	40,8	<0,005	29,2	1,87	<0,005	1,78	8,7	2,0	0,8	53	0,005	0,40
27-04-2023	**49.594**	31	4,2	10,46	7,69	434	0,01	0	0,084	32,1	18,0	<0,005	55,0	1,99	0,202	2,15	12,8	3,0	1,2	62	0,017	0,12
27-04-2023	**49.594**	36	4,6	11,4	7,71	436	0,01	0	0,088	31,9	18,7	<0,005	55,5	4,18	0,168	1,82	12,2	3,0	1,2	63	0,012	0,12
27-04-2023	**49.594**	41	2,7	11,49	8	437	0,01	2,7	0,080	31,4	19,6	<0,005	54,6	1,96	0,145	2,23	12,1	3,0	1,1	63	0,011	0,12
01-05-2023	**49,386**	52			7,75	460	0	21,7	0,067	24,0	35,4	<0,005	25,0	2,84	<0,005	2,97	11,6	5,3	1,0	58	0,03	0,03
01-05-2023	**49,386**	68			7,88	457	0	19,5	0,061	24,1	36,7	<0,005	24,8	2,86	<0,005	3,21	11,6	5,3	0,9	58	0,03	0,06
01-05-2023	**49,386**	84			7,68	437	0	23,9	0,064	24,0	41,3	<0,005	24,2	2,98	<0,005	2,93	11,3	5,2	0,9	60	0,02	0,03

Tabel 2. Water Chemistry of existing wells Villestrup 2023. continued from Table 7.

		depth	**Si**	**Al**	**As**	**Br**	**Cr**	**Cu**	δO18	δD	d-excess (‰)	δO18	δD	d-excess
Date	DGUnr.	mbs	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	**Reportable value (‰)**			**Reportable st.dev. (‰)**		
25-04-2023	**49.378**	30,5	7,19	92,26	0,05	105	<0,5	5,99						
25-04-2023	**49.378**	38	10,02	4,09	0,38	109	<0,5	1,52	-8,89	-60,32	10,6	0,10	0,06	0,83
25-04-2023	**49.378**	45,5	10,47	1,88	0,48	102	<0,5	1,16	-8,95	-60,11	11,2	0,10	0,18	0,73
25-04-2023	**49.378**	53	10,54	1,26	0,44	100	<0,5	1,05	-8,94	-60,42	10,9	0,12	0,22	1,07
25-04-2023	**49.1002**	61	11,67	<0,5	2,40	466	<0,5	5,19	-8,85	-59,94	10,6	0,16	0,11	1,28
25-04-2023	**49.1002**	73	11,90	3,04	2,01	1.424	<0,5	15,78	-8,96	-60,78	10,6	0,10	0,31	1,00
26-04-2023	**49.448**	47	10,24	<0,5	0,44	58	<0,5	0,98	-8,99	-60,87	10,8	0,14	0,29	1,32
26-04-2023	**49.448**	59	10,33	<0,5	0,37	59	<0,5	1,12	-8,97	-60,74	10,8	0,09	0,11	0,78
26-04-2023	**49.448**	65	10,48	0,72	0,33	54	<0,5	0,95	-9,01	-60,55	11,3	0,11	0,14	0,92
26-04-2023	**49.385**	33	9,93	<0,5	1,61	103	<0,5	2,96	-9,12	-60,03	12,5	0,07	0,26	0,71
26-04-2023	**49.385**	37	10,49	1,46	1,87	104	<0,5	3,21	-8,97	-60,33	11,1	0,11	0,07	0,85
26-04-2023	**49.385**	41	10,35	5,43	6,26	103	<0,5	2,99	-9,05	-60,15	11,9	0,07	0,10	0,59
26-04-2023	**49.385**	45	10,17	<0,5	1,64	103	<0,5	2,09	-8,95	-60,42	11,0	0,09	0,25	0,86
27-04-2023	**49.965**	93	9,20	<0,5	0,08	93	<0,5	0,58	-8,84	-59,82	10,7	0,03	0,24	0,34
27-04-2023	**49.965**	97,6	9,98	<0,5	0,33	90	<0,5	1,18	-8,93	-59,89	11,2	0,10	0,25	0,91
27-04-2023	**49.965**	102,2	9,85	<0,5	0,42	95	<0,5	0,69	-8,93	-60,06	11,0	0,05	0,06	0,41
27-04-2023	**49.965**	106,8	9,83	<0,5	0,50	97	<0,5	0,96	-9,06	-59,93	12,1	0,06	0,16	0,53
27-04-2023	**49.594**	31	7,74	13,48	1,05	103	<0,5	0,89	-8,83	-60,33	10,1	0,02	0,14	0,29
27-04-2023	**49.594**	36	7,96	<0,5	1,30	103	<0,5	1,11	-8,90	-60,15	10,8	0,04	0,22	0,50
27-04-2023	**49.594**	41	8,19	<0,5	1,37	101	<0,5	0,85	-8,91	-60,16	10,9	0,15	0,14	1,24
01-05-2023	**49,386**	52		6,02	1,15	88	<0,5	1,95	-8,80	-59,70	10,5	0,10	0,11	0,78
01-05-2023	**49,386**	68		3,57	1,15	90	<0,5	2,13	-8,76	-59,76	10,1	0,11	0,13	0,88
01-05-2023	**49,386**	84		1,86	1,30	92	<0,5	1,03	-8,74	-59,60	10,2	0,10	0,15	0,86

Tabel 3. Water Chemistry from water samples from new Geoprobe Villestrup 2023. continues in Tabel 4

		depth	Temp	O2	pH	EC	Fe(field)	NO3(field)	F	Cl	NO3	PO4	SO4	HCO3	NH4	DOC	Na	Mg	K	Ca	Mn	Fe
Date	DGUnr.	mbs		mg/l		µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	meq/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
02-05-2023	49.2527	2,5	8,9	5,74	7,68	492			0,040	26,4	107	<0,005	18,9	1,75	0,177	2,32	16,9	5,2	7,4	62	0,70	0,30
02-05-2023	49.2527	4,50	9,40	5,44	8,07	618			0,021	56,7	68,6	<0,005	24,6	2,85	0,192	1,39	30,3	7,1	3,2	65	0,65	0,08
02-05-2023	49.2527	6,5	10,2	4,99	8,03	522			0,017	23,3	66,0	<0,005	22,3	3,10	0,061	0,84	12,6	6,7	1,6	65	0,11	0,18
02-05-2023	49.2527	8,50	10,40	4,31	7,99	578			0,014	39,9	65,9	<0,005	20,8	3,26	0,075	1,17	16,5	7,4	1,8	72	0,12	0,10
02-05-2023	49.2527	10,50	10,00	2,21	7,97	555	0	13,3	0,047	59,3	32,2	<0,005	29,4	2,76	0,033	0,87	22,8	5,7	1,6	69	0,57	0,10
02-05-2023	49.2527	12,50	12,50	0,24	7,91	354	1	0,0	0,109	24,7	<0,05	<0,005	44,3	1,90	0,022	0,32	11,7	2,4	1,9	49	0,03	0,14
02-05-2023	49.2527	14,50	12,50	0,15	7,96	364	0,07	0,0	0,122	24,8	<0,05	<0,005	44,9	1,84	0,052	0,55	12,4	2,5	2,5	50	0,02	0,26
02-05-2023	49.2527	16,50	10,10	0,13	7,91	352	0,05	0,0	0,098	24,8	<0,05	<0,005	44,8	1,87	0,023	0,50	11,8	2,3	1,4	50	0,02	0,08
02-05-2023	49.2527	18,50		1,62	7,58	342	<0,01	0,0	0,113	19,8	<0,05	<0,005	40,1	1,86	0,010	0,48	11,9	2,3	1,2	51	0,02	0,12
02-05-2023	49.2527	20,50		0,12	7,64	345	<0,01	0,0	0,103	24,7	<0,05	<0,005	44,8	1,87	0,044	0,57	11,8	2,3	1,3	51	0,09	0,10
02-05-2023	49.2527	22,50		0,67	8,2	371	<0,01	0,0	0,098	21,5	<0,05	<0,005	44,8	1,88	0,027	0,46	12,4	2,3	1,2	51	0,06	0,10
01-05-2023	49.2528	12,50		0,26	7,92	531	0,1	37,2	0,022	16,6	55,9	<0,005	15,1	3,76	0,295	1,46	10,1	6,2	3,0	86	0,50	1,26
01-05-2023	49.2528	14,50		7,56	8,05	494	<0,01	48,3	0,025	15,4	68,2	<0,005	15,7	3,08	0,043	1,38	6,8	4,5	1,5	81	0,05	0,13
01-05-2023	49.2528	16,50		8,16	8,16	530	<0,01	73,1	0,012	17,0	81,6	<0,005	16,4	3,18	0,082	0,94	8,1	6,4	1,3	84	0,10	0,12
01-05-2023	49.2528	18,50		5,37	8,05	509	<0,01	63,3	0,021	19,7	87,0	<0,005	19,4	2,65	0,148	1,45	9,7	7,7	1,7	71	0,17	0,10
01-05-2023	49.2528	20,50		4,6	8,1	492	<0,01	39,4	0,022	19,4	58,9	<0,005	24,9	2,91	0,077	1,59	11,2	7,6	1,4	72	0,07	0,12
01-05-2023	49.2529	10,50		4,95	7,98	663	<0,01	85,9	0,027	60,3	43,0	<0,005	25,3	3,68	0,198	1,60	29,3	6,4	1,9	82	0,20	0,09
01-05-2023	49.2529	12,50		6,17	7,84	720	<0,01	46,5	0,030	58,1	62,1	<0,005	28,8	4,06	0,352	1,37	26,3	7,9	2,9	98	0,12	0,18
01-05-2023	49.2529	14,50		8,78	7,73	711	<0,01	141,7	0,030	56,3	65,1	0,008	29,5	3,91	0,109	1,45	26,2	7,0	1,5	98	0,04	0,12
01-05-2023	49.2529	16,50		8,86	7,88	719	<0,01	116,9	0,022	56,7	67,3	<0,005	29,1	4,02	0,107	1,14	28,0	7,6	1,6	107	0,09	0,35
01-05-2023	49.2529	18,50		8,17	7,62	719	<0,01	34,1	0,020	59,2	60,2	<0,005	30,3	3,72	0,124	1,03	26,9	6,8	1,8	99	0,09	0,17
01-05-2023	49.2529	20,50		0,42	7,74	591	0,07	43,8	0,059	50,9	34,7	<0,005	34,3	3,20	0,207	1,44	24,9	6,0	3,1	80	0,22	0,20
01-05-2023	49.2529	22,5		0,07	7,88	432	0,1	0,0	0,120	30,7	3,26	<0,005	30,7	2,82	0,254	0,84	15,5	4,8	3,5	57	0,08	0,52
04-05-2023	49.2530	4,5	9,8	8,73	7,15	353			0,043	42,6	25,5	<0,005	26,6		0,008	1,93	14,2	3,6	6,4	32	0,13	0,29
04-05-2023	49.2530	6,50	10,50	6,87	7,73	741	<0,01	21,3	0,100	90,4	28,6	<0,005	34,2	3,38	0,130	2,04	20,6	7,8	8,2	94	0,75	0,19
04-05-2023	49.2530	7,00			7,6	671								3,72		2,15	26,4	8,0	2,1	90	0,07	0,11
04-05-2023	49.2530	8,00			7,45	597			0,027	48,4	49,3	0,009	23,9	3,26	<0,005	2,10	23,2	6,5	1,4	72	0,03	0,08
04-05-2023	49.2530	9,00			7,76	642			0,084	51,2	14,4	<0,005	32,2	3,32	1,369	16,9	28,9	7,0	4,3	68	0,59	0,06
04-05-2023	49.2530	10,00			7,5	984			0,021	173	35,2	<0,005	19,5	3,49	<0,005	2,67	68,8	7,4	2,4	101	0,06	0,12
04-05-2023	49.2530	11,00			7,61	865								3,37			49,2	6,7	2,9	89	0,86	0,14
04-05-2023	49.2530	20,50	9,60	8,78	7,64	591	<0,01	56,2	0,029	14,2	72,9	<0,005	26,9	3,67	0,034	1,43	10,0	4,2	1,2	93	0,11	0,10
04-05-2023	49.2530	22,50	10,50	5,8	7,78	579	<0,01	54,5	0,029	13,6	71,5	<0,005	25,5	3,45	0,015	1,35	9,6	4,2	1,0	89	0,07	0,10

Tabel 4. Water Chemistry from water samples from new Geoprobe Villestrup 2023. continued from Tabel 3.

		depth	**Al**	**As**	**Br**	**Cr**	**Cu**	δO18	δD	d-excess (‰)	δO18	δD	d-excess
Date	**DGUnr.**	**mbs**	µg/l	µg/l	µg/l	µg/l	µg/l	**Reportable value (‰)**			**Reportable st.dev. (‰)**		
02-05-2023	49.2527	2,5	35,04	0,53	76	<0,5	2,86	-8,34	-55,99	10,38	0,06	0,19	0,54
02-05-2023	49.2527	4,50	4,34	0,59	101	<0,5	1,72	-8,59	-57,58	10,78	0,13	0,31	1,15
02-05-2023	49.2527	6,5	2,10	0,34	96	<0,5	0,88	-8,79	-58,85	11,17	0,09	0,27	0,79
02-05-2023	49.2527	8,50	0,51	0,40	97	<0,5	2,98	-8,81	-58,40	11,73	0,12	0,14	0,95
02-05-2023	49.2527	10,50	1,58	13,41	109	<0,5	1,04	-8,99	-60,67	11,00	0,06	0,25	0,62
02-05-2023	49.2527	12,50	0,69	1,82	94	<0,5	0,44	-9,05	-61,48	10,77	0,13	0,36	1,25
02-05-2023	49.2527	14,50	1,46	1,33	94	<0,5	0,44	-9,08	-61,29	11,16	0,15	0,14	1,26
02-05-2023	49.2527	16,50	1,15	1,93	94	<0,5	0,44	-8,96	-61,47	10,08	0,13	0,39	1,32
02-05-2023	49.2527	18,50	0,87	2,27	75	<0,5	0,47	-9,13	-61,31	11,51	0,09	0,05	0,67
02-05-2023	49.2527	20,50	1,16	2,01	93	<0,5	0,58	-9,11	-61,08	11,59	0,10	0,05	0,78
02-05-2023	49.2527	22,50	4,71	1,96	80	<0,5	0,48	-9,14	-61,36	11,59	0,12	0,15	0,84
01-05-2023	49.2528	12,50	7,69	0,37	75	<0,5	2,01	-8,14	-53,00	11,65	0,09	0,23	0,92
01-05-2023	49.2528	14,50	5,38	0,25	75	1,04	1,61	-8,18	-53,94	11,06	0,10	0,30	0,84
01-05-2023	49.2528	16,50	7,14	0,23	84	<0,5	1,29	-8,57	-55,74	12,41	0,11	0,10	0,82
01-05-2023	49.2528	18,50	7,38	0,31	89	<0,5	1,85	-8,54	-57,07	10,93	0,10	0,15	0,88
01-05-2023	49.2528	20,50	11,78	0,78	96	<0,5	1,19	-8,88	-59,56	11,19	0,04	0,14	0,44
01-05-2023	49.2529	10,50	4,00	0,49	141	<0,5	1,83	-8,53	-57,98	10,04	0,05	0,07	0,45
01-05-2023	49.2529	12,50	5,28	0,53	159	<0,5	1,98	-8,83	-59,15	11,21	0,07	0,13	0,64
01-05-2023	49.2529	14,50	3,23	0,45	155	<0,5	1,45	-8,79	-59,53	10,59	0,07	0,20	0,68
01-05-2023	49.2529	16,50	33,45	0,47	156	<0,5	1,60	-8,81	-59,12	11,09	0,03	0,14	0,28
01-05-2023	49.2529	18,50	5,76	0,44	156	<0,5	1,80	-8,86	-59,56	11,12	0,03	0,14	0,28
01-05-2023	49.2529	20,50	15,92	12,41	136	<0,5	2,71	-8,91	-59,97	11,12	0,04	0,15	0,17
01-05-2023	49.2529	22,5	6,67	0,71	87	<0,5	0,72	-8,95	-61,06	10,37	0,21	0,48	1,87
04-05-2023	49.2530	4,5	9,84	0,32	157	<0,5	1,78	-9,05	-61,12	11,06	0,16	0,31	1,35
04-05-2023	49.2530	6,50	18,19	0,69	238	<0,5	1,47	-8,43	-55,05	11,91	0,10	0,13	0,86
04-05-2023	49.2530	7,00	5,26	0,54	0	<0,5	1,39	-8,62	-57,30	11,34	0,05	0,09	0,41
04-05-2023	49.2530	8,00	4,21	0,52	138	<0,5	1,33	-8,55	-57,55	10,57	0,06	0,25	0,50
04-05-2023	49.2530	9,00	5,39	0,47	187	<0,5	2,07	-8,48	-57,05	10,51	0,12	0,17	1,03
04-05-2023	49.2530	10,00	4,81	0,94	135	<0,5	3,03	-8,35	-56,22	10,31	0,08	0,20	0,46
04-05-2023	49.2530	11,00	51,92	1,18	0	<0,5	2,64	-8,48	-56,80	10,73	0,08	0,17	0,78
04-05-2023	49.2530	20,50	4,88	0,37	96	<0,5	1,16	-8,22	-53,87	11,44	0,09	0,22	0,88
04-05-2023	49.2530	22,50	11,70	0,40	101	<0,5	1,20	-8,06	-53,55	10,51	0,04	0,10	0,35

Tabel 5. Water Chemistry from sediment samples from new Geoprobe Villestrup 2023. continues in Tabel 6

		depth	F	Cl	NO3	PO4	SO4	NH4	TIC	DOC	Na	Mg	K	Ca	Mn	Fe
Date	DGUnr.	mbs	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
02-05-2023	49.2527	2,35	0,27	23,2	26,89	<0,005	31,54	0,094	9,51	58	15,8	3,7	5,2	28	0,10	
02-05-2023	49.2527	3,44	0,13	31,86	62,6	<0,005	26,74	0,055	46,2	34	18,5	6,3	7,1	92	0,07	0,19
02-05-2023	49.2527	4,66	0,18	100,15	22,8	0,060	62,13	0,322	23,3	109	47,7	5,8	5,6	69	0,11	0,10
02-05-2023	49.2527	10,23	0,25	76,53	33,75	0,080	35,63	0,062	37,2	15	32,1	7,0	4,0	83	0,98	0,12
02-05-2023	49.2527	10,55	0,22	47,2	12,61	<0,005	42,61	0,317	35,0	26	24,6	5,2	3,5	73	0,04	0,07
02-05-2023	49.2527	11,82	0,94	27,74	<0,05	<0,005	32,98			37	18,3	3,1	2,9	40	0,05	
02-05-2023	49.2527	13,08	0,64	33,52	<0,05	<0,005	65,1			34	15,6	2,6	3,0	55	0,05	0,23
02-05-2023	49.2527	13,08	1,32	36,32	1,9	<0,005	84,9			67	28,7	3,5	2,8	50	0,01	
02-05-2023	49.2527	15,20														
01-05-2023	49.2528	7,18	1,06	42,54	41,16	<0,005	68,74				37,6	6,6	4,0	76	0,01	0,12
01-05-2023	49.2528	9,62	0,3	268,92	24,68	0,120	16,4			74	207,4	2,7	3,4	54	0,09	0,03
01-05-2023	49.2528	10,76	0,1	22,24	54,44	<0,005	19,32	0,027		32	16,7	7,8	2,4	116	0,15	0,20
01-05-2023	49.2528	11,96	0,31	21,64	54,82	<0,005	27,65	0,414	41,5	77	25,0	5,7	4,4	71	0,05	
01-05-2023	49.2529	2,07	<0,005	13,68	61,42	<0,005	35,18	0,195		90	14,2	3,4	13,8	18	0,46	
01-05-2023	49.2529	4,39	0,2	27,18	137	<0,005	35,38	0,283		129	19,8	6,6	12,1	41	0,45	
01-05-2023	49.2529	5,96	0,36	112,36	37,94	0,900	32,36	0,316	45,8	85	70,8	8,5	4,5	96	0,05	0,06
01-05-2023	49.2529	7,17	0,1	71,8	19,7	<0,005	32,27	0,261	50,8	76	45,5	7,6	3,1	95	0,45	0,05
01-05-2023	49.2529	8,36	0,15	83,91	23,49	<0,005	43,51	0,412	34,7	123	52,2	5,8	4,0	70	0,15	0,03
01-05-2023	49.2529	9,56	0,19	66,55	27,86	<0,005	38,23	0,425	45,6	79	32,8	7,3	3,7	90	0,74	0,04
01-05-2023	49.2529	10,82	0,12	106,96	40,42	<0,005	31,5			61	43,7	5,8	3,1	83	0,02	0,18
01-05-2023	49.2529	11,96	0,19	57,54	47,83	0,210	35,34	0,404	32,7	72	27,8	5,5	2,9	77	0,03	0,06
04-05-2023	49.2530	3	0,18	158,15	2,33	<0,005	36,71	0,307	22,5	101	59,7	6,0	3,9	65	0,04	0,02
04-05-2023	49.2530	4,635	0,1	48,31	27,61	<0,005	35,45	0,238	9,62	65	18,0	4,2	4,7	37	0,05	
04-05-2023	49.2530	5,855	0,08	76,48	20,51	<0,005	30,47	0,283	4,83	73	18,9	4,4	8,7	40	0,14	
04-05-2023	49.2530	7,075	0,17	59,83	41,19	<0,005	45,63	0,274	8,70	45	26,1	5,4	6,6	42	0,26	
04-05-2023	49.2530	8,295	0,07	133,19	20,24	<0,005	53,29	0,259	5,67	47	49,8	8,2	2,4	43	0,59	
04-05-2023	49.2530	9,515	0,13	61,06	45	<0,005	42,6	0,293	48,4	46	21,9	10,6	2,7	102	0,18	0,09
04-05-2023	49.2530	10,735	2,08	74,4	41,46	<0,005	104,66	no sample		134						
04-05-2023	49.2530	11,955	0,56	49,46	78,92	<0,005	58,24			132	35,2	4,9	3,3	82	0,04	0,07

Tabel 6. Water Chemistry from sediment samples from new Geoprobe Villestrup 2023. continued from Tabel 5.

		depth	Si	Al	As	Br	Cr	Cu	δO18	δD	-excess (‰	δO18	δD	d-excess
Date	**DGUnr.**	**mbs**	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	**Reportable value (‰)**			**Reportable st.dev. (‰)**		
02-05-2023	49.2527	2,35	8,54	83,87	0,30	<5	0,86	25,43	-8,90	-60,18	10,76	0,10	0,16	0,84
02-05-2023	49.2527	3,44	13,23	91,96	0,32	<5	0,52	18,49	-8,22	-54,54	10,73	0,08	0,15	0,69
02-05-2023	49.2527	4,66	14,22	132,48	1,68	150	1,49	21,14	-8,33	-56,04	10,20	0,16	0,20	1,36
02-05-2023	49.2527	10,23	11,38	158,09	1,32	90	17,75	57,05	-9,02	-60,34	11,54	0,08	0,22	0,70
02-05-2023	49.2527	10,55	16,53	158,30	2,01	90	2,18	43,45	-9,00	-61,28	10,49	0,08	0,10	0,54
02-05-2023	49.2527	11,82	20,22	131,76	3,02	<5	0,98	51,99	-8,93	-60,79	10,44	0,08	0,16	0,56
02-05-2023	49.2527	13,08	6,27	234,49	1,98	100	1,95	33,56	-8,57	-61,12	9,13	0,09	0,39	0,86
02-05-2023	49.2527	13,08	11,75	138,77	3,56	<5	0,74	35,59	-8,93	-60,49	10,79	0,15	0,32	1,33
02-05-2023	49.2527	15,20												
01-05-2023	49.2528	7,18	18,33	110,72	0,61	<5	5,12	45,56	-7,79	-54,13	7,83	0,15	0,36	1,43
01-05-2023	49.2528	9,62	14,36	126,01	1,58	<5	448,18	26,42	-8,16	-55,32	9,58	0,20	0,21	1,65
01-05-2023	49.2528	10,76	16,15	81,25	0,00	<5	76,58	18,57	-8,45	-55,36	11,86	0,12	0,28	0,81
01-05-2023	49.2528	11,96	14,79	149,86	0,00	<5	56,75	34,19	-8,15	-53,37	11,44	0,03	0,25	0,48
01-05-2023	49.2529	2,07	8,74	301,54	0,00	<5	0,42	49,58	-8,56	-54,54	13,54	0,07	0,13	0,63
01-05-2023	49.2529	4,39	12,54	99,83	0,00	<5	<0,5	102,31	-8,50	-55,14	12,50	0,04	0,14	0,33
01-05-2023	49.2529	5,96	15,49	120,02	0,55	<5	0,62	177,49	-8,54	-55,94	12,04	0,07	0,25	0,75
01-05-2023	49.2529	7,17	13,91	128,95	0,19	<5	<0,5	17,23	-8,73	-57,79	11,74	0,20	0,26	1,73
01-05-2023	49.2529	8,36	13,07	124,70	0,42	<5	0,83	20,09	-8,56	-56,53	11,62	0,05	0,10	0,49
01-05-2023	49.2529	9,56	14,06	149,52	0,00	<5	140,26	23,44	-8,57	-57,02	11,22	0,07	0,24	0,45
01-05-2023	49.2529	10,82	13,08	123,26	0,07	100	581,74	181,38	-8,48	-57,36	10,27	0,06	0,11	0,57
01-05-2023	49.2529	11,96	13,95	127,24	0,00	120	209,92	20,91	-8,57	-57,77	10,57	0,12	0,21	1,11
04-05-2023	49.2530	3	4,94	139,52	0,05	160	6,67	27,83	-10,05	-69,26	11,21	0,08	0,14	0,59
04-05-2023	49.2530	4,635	7,10	135,49	0,00	<5	1,70	19,51	-9,26	-62,60	11,30	0,14	0,20	1,27
04-05-2023	49.2530	5,855	7,34	186,05	0,00	160	1,49	17,82	-8,72	-58,05	11,37	0,12	0,11	0,87
04-05-2023	49.2530	7,075	7,30	126,88	0,00	140	0,43	20,97	-8,19	-54,73	10,35	0,12	0,27	1,12
04-05-2023	49.2530	8,295	9,44	165,41	0,00	220	0,43	23,07	-7,52	-49,12	10,43	0,04	0,09	0,33
04-05-2023	49.2530	9,515	16,11	121,60	0,00	130	0,73	19,11	-8,16	-54,78	10,15	0,07	0,13	0,39
04-05-2023	49.2530	10,735				140								
04-05-2023	49.2530	11,955	19,02	156,18	0,10	180	5,61	31,43	-8,19	-55,82	10,13	0,14	0,27	1,22

Appendix 4: Gasanalyses Villestrup

Tabel 7 Gas analyses from existing wells Villestrup 2023.

Dato	Well	Depth	CH_4	N_2O	O_2	pH	EC	Nitrate (field)
	DGU nr.	m b.s.	ppmV	ppmV	mg/l		µS/cm	mg/l
25-05-2023	**49.378**	30.5	131	10.51				
25-05-2023	**49.378**	38	22.9	5.25	10.1	7.07	517	47
25-05-2023	**49.378**	45.5	24.2	5.77	10.4	7.58	501	50
25-05-2023	**49.378**	53	16.9	5.77	10.3	7.22	496	45
25-04-2023	**49.1002**	61	10.9	0.21	7.3	7.48	1384	<1
25-04-2023	**49.1002**	73	25.3	0.18	7.5	7.68	3260	<1
26-04-2023	**49.448**	47	0.81	0.40	9.0	7.02	396	<1
26-04-2023	**49.448**	59	0.19	0.45	9.1	7.43	387	<1
26-04-2023	**49.448**	65	0.24	0.33	9.6	7.16	384	<1
26-04-2023	**49.385**	33			10.3	7.7	480	14
26-04-2023	**49.385**	37	0.27	18.82	9.1	7.78	478	19
26-04-2023	**49.385**	41	0.06	16.74	10.4	7.84	475	19
26-04-2023	**49.385**	45	0.04	18.28	10.7	7.99	471	50
27-04-2023	**49.965**	93	0.17	5.12	8.1		361	
27-04-2023	**49.965**	97.6	0.21	5.13	10.4	7.64	375	31
27-04-2023	**49.965**	102.2	0.20	4.76	9.9	7.71	366	31
27-04-2023	**49.965**	106.8	0.06	4.75	9.3	7.8	363	28
27-04-2023	**49.594**	31	3.17	1.52	10.5	7.69	434	<1
27-04-2023	**49.594**	36	4.10	1.47	11.4	7.71	436	<1
27-04-2023	**49.594**	41	3.83	2.04	11.5	8	437	3
01-05-2023	**49.386**	52	0.12	5.67		7.75	460	22
01-05-2023	**49.386**	68	0.00	6.08		7.88	457	19
01-05-2023	**49.386**	84	0.04	6.08		7.68	437	24

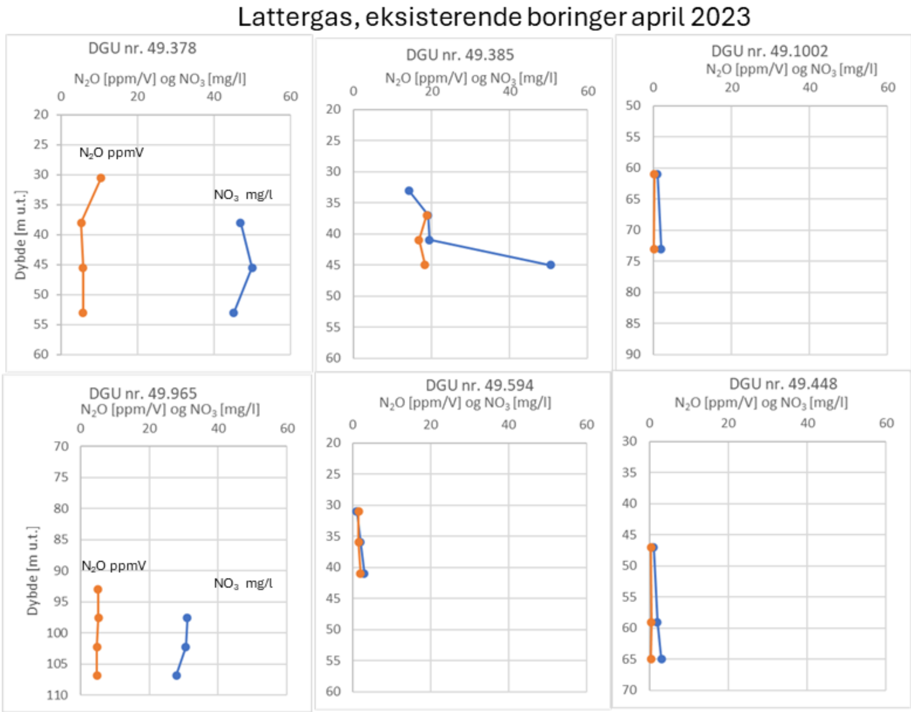


Figure 4.1 Results for N_2O and nitrate in existing wells. Villestrup 2023. Data in table 1

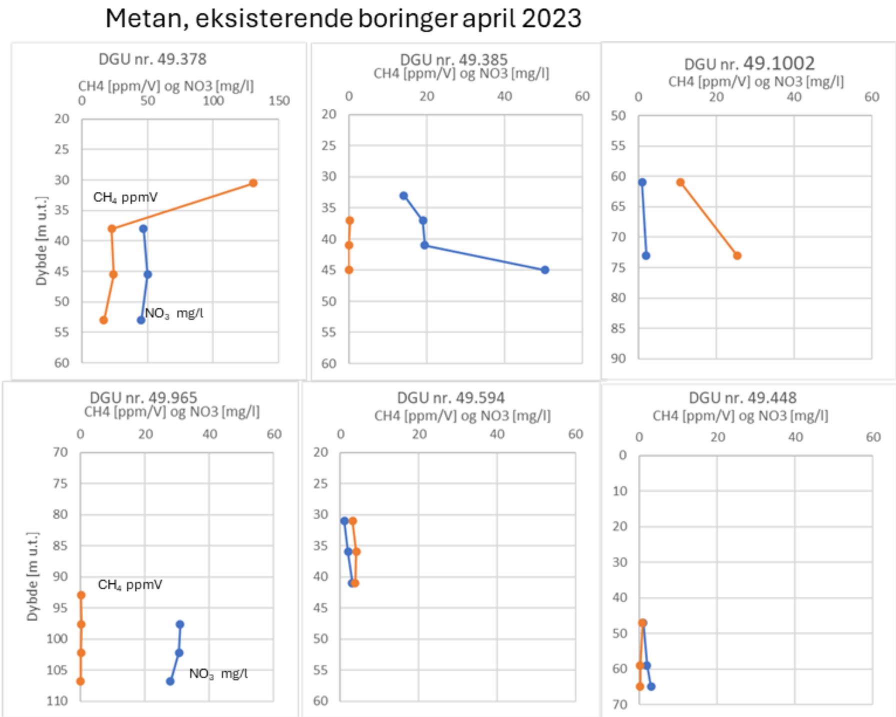


Figure 4.2. Results for CH_4 and nitrate in existing wells. Villestrup 2023. Data in Tabel 7.

Tabel 8. Gas analyses from new Geoprobe wells. Villestrup 2023.

Dato	Well no.	DGU nr.	Depth m b.s.	CH_4 ppmV	N_2O ppmV	O2 mg/l	EC µS/cm	pH	Nitrate (field) mg/l
03-05-2023	V1	**49.2527**	2.5	55.70	5.34	5.74	492	7.68	n.a.
03-05-2023	V1	**49.2527**	4.5	56.24	18.60	5.44	618	8.07	n.a.
03-05-2023	V1	**49.2527**	6.5	5.33	16.33	4.99	522	8.03	n.a.
03-05-2023	V1	**49.2527**	8.5	6.21	12.35	4.31	578	7.99	n.a.
03-05-2023	V1	**49.2527**	10.5	9.08	5.53	2.21	555	7.97	13
03-05-2023	V1	**49.2527**	12.5	22.17		0.24	354	7.91	<1
03-05-2023	V1	**49.2527**	14.5	36.37		0.15	364	7.96	<1
03-05-2023	V1	**49.2527**	16.5	10.18	0.02	0.13	352	7.91	<1
03-05-2023	V1	**49.2527**	18.5	3.86		1.62	342	7.58	<1
03-05-2023	V1	**49.2527**	20.5	3.97	<0.005	0.12	345	7.64	<1
03-05-2023	V1	**49.2527**	22.5	12.54	0.08	0.67	371	8.2	<1
02-05-2023	V2	**49.2528**	12.5	17.04	3.12	0.26	531	7.92	37
02-05-2023	V2	**49.2528**	14.5	5.62	3.61	7.56	494	8.05	48
02-05-2023	V2	**49.2528**	16.5	13.46	11.83	8.16	530	8.16	73
02-05-2023	V2	**49.2528**	18.5	32.83	19.15	5.37	509	8.05	63
02-05-2023	V2	**49.2528**	20.5	14.00	37.04	4.6	492	8.1	39
01-05-2023	V3	**49.2529**	10.5	2.61	0.48	4.95	663	7.98	86
01-05-2023	V3	**49.2529**	12.5	45.85	3.62	6.17	720	7.84	47
01-05-2023	V3	**49.2529**	14.5	28.91	5.88	8.78	711	7.73	140
01-05-2023	V3	**49.2529**	16.5	27.19	4.78	8.86	719	7.88	117
01-05-2023	V3	**49.2529**	18.5	12.51	3.49	8.17	719	7.62	34
01-05-2023	V3	**49.2529**	20.5	67.29	2.94	0.42	591	7.74	44
01-05-2023	V3	**49.2529**	22.5	48.76	0.25	0.07	432	7.88	<1
04-05-2023	V4	**49.2530**	4.5	10.66	4.70	8.73	3.53	7.15	n.a.
04-05-2023	V4	**49.2530**	6.5	26.75	5.20	6.87	741	7.73	21
04-05-2023	V4	**49.2530**	20.5	6.27	9.84	8.78	591	7.64	56
04-05-2023	V4	**49.2530**	22.5	4.70	11.54	5.8	579	7.78	54

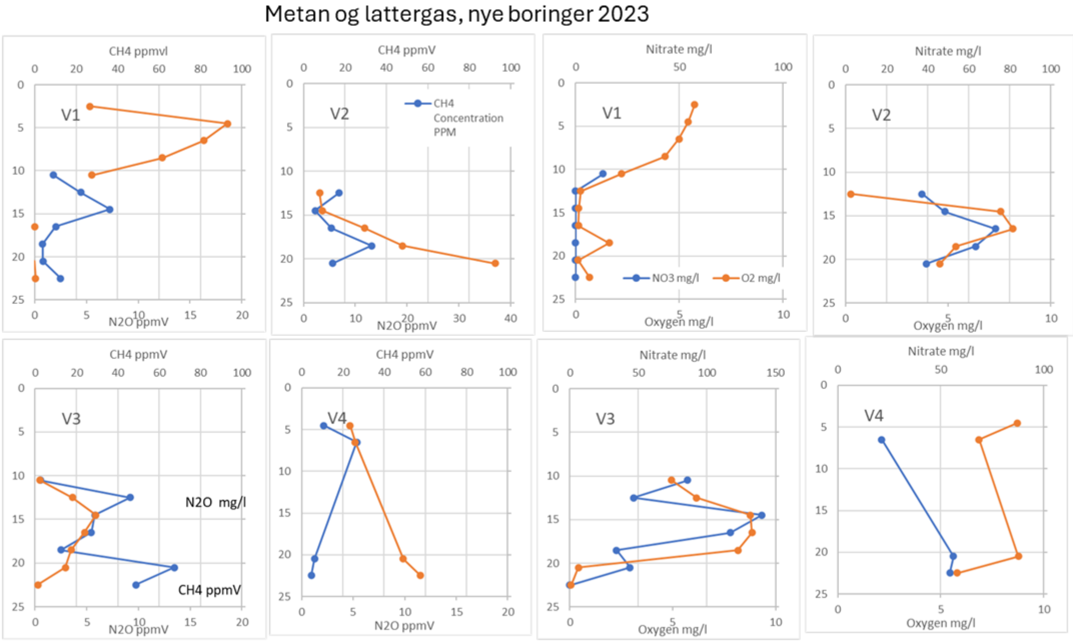


Figure 4.3. To the left: CH_4 and N_2O. To the right O_2 and NO_3 in new Geoprobe wells. Villestrup. 2023. Data in Tabel 8.

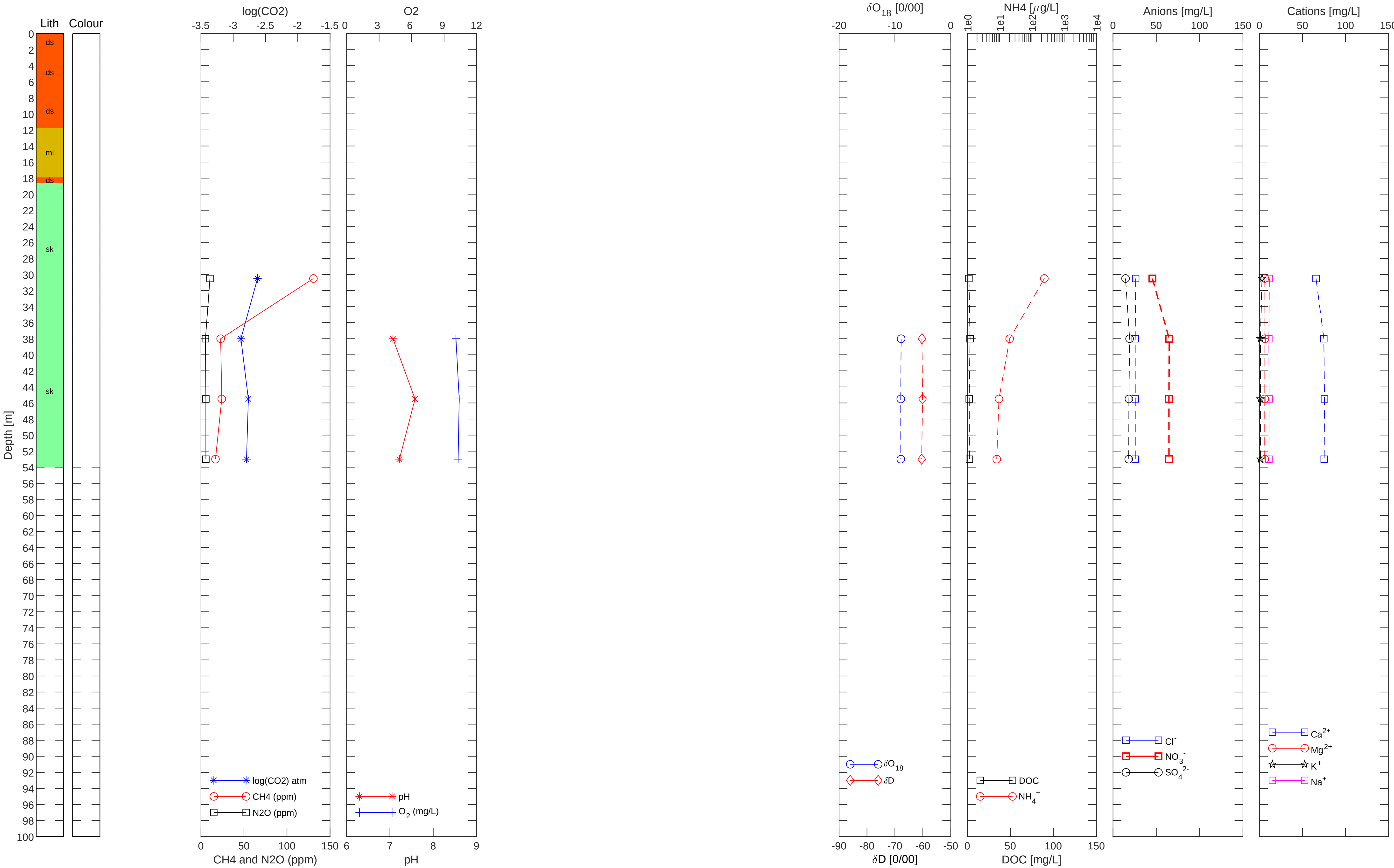
Appendix 5. Sediment analyses

Tabel 9. Results from the sediment analyses.

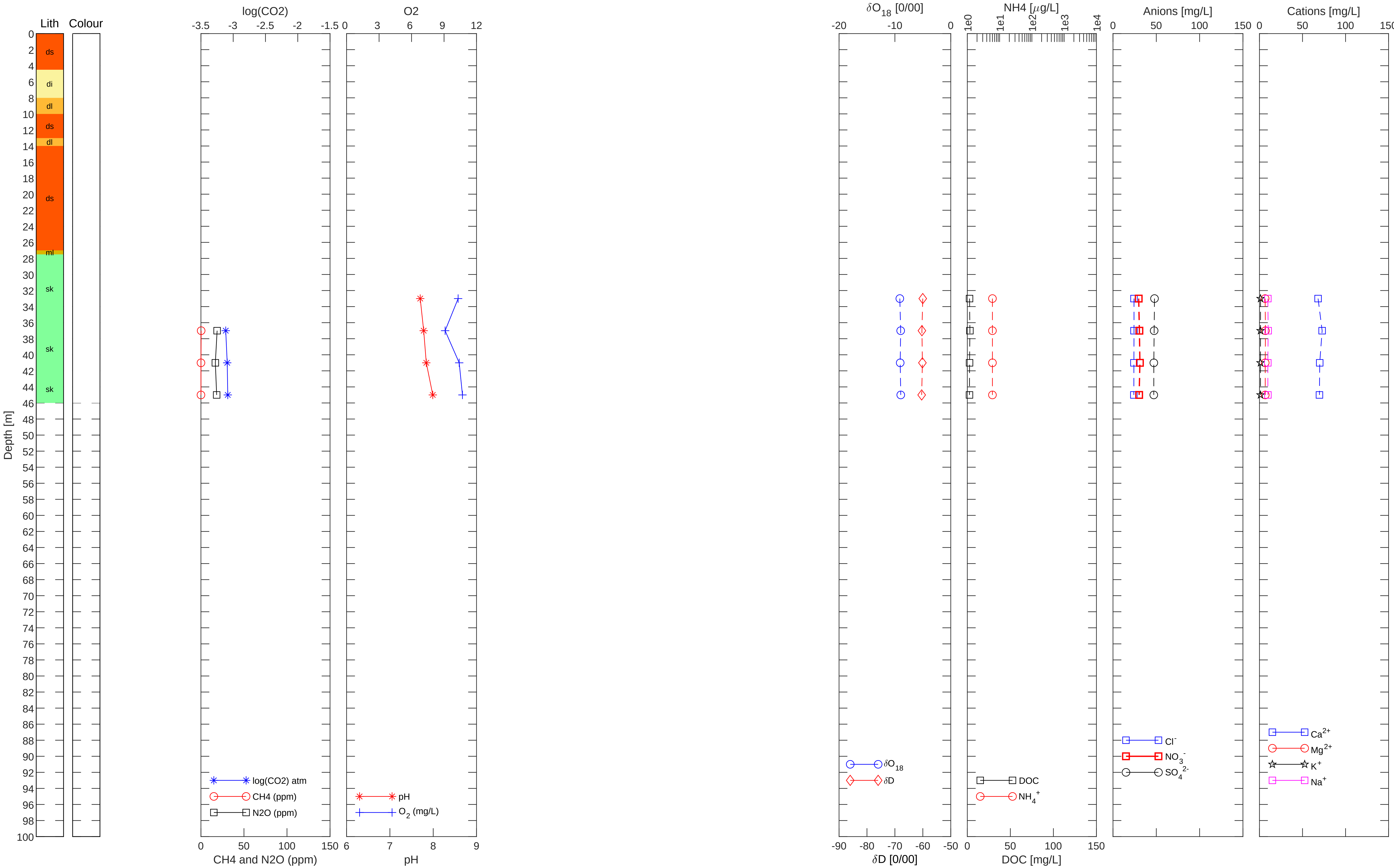
			Depth	$Fe(II)/Fe_{tot}$	Fe(II)	Fe_{tot}
Date	DGU nr.	Label	m b.s.	ratio	mg/g dry	mg/g dry
03-05-2023	49.2527	V1-3	3.53	0.59	0.0933	0.1570
03-05-2023	49.2527	V1-4	4.75	0.19	0.0360	0.1898
03-05-2023	49.2527	V1-X	10.63	0.02	0.0014	0.0878
03-05-2023	49.2527	V1-X	11.72	0.96	0.3060	0.3174
03-05-2023	49.2527	V1-X	12.98	0.95	1.0544	1.1068
03-05-2023	49.2527	V1-X	12.98	0.97	0.2619	0.2695
03-05-2023	49.2527	V1-X	15.1	0.93	0.2956	0.3166
02-05-2023	49.2528	V2-3	10.85	0.26	0.0175	0.0674
02-05-2023	49.2528	V2-4	12.05	0.19	0.0121	0.0647
01-05-2023	49.2529	V3-4	7.24	0.20	0.0102	0.0514
01-05-2023	49.2529	V3-5	8.44	0.14	0.0073	0.0516
01-05-2023	49.2529	V3-6	9.65	0.62	0.2226	0.3598
01-05-2023	49.2529	V3-7	10.89	0.06	0.0101	0.1726
01-05-2023	49.2529	V3-8	12.05	0.33	0.0583	0.1750
04-05-2023	49.2530	V4-3	3.51	0.02	0.0013	0.0790
04-05-2023	49.2530	V4-4	4.73	1.74	0.3006	0.1723
04-05-2023	49.2530	V4-5	5.95	0.19	0.0155	0.0816
04-05-2023	49.2530	V4-6	7.17	0.40	0.0682	0.1686
04-05-2023	49.2530	V4-7	8.39	0.53	0.2084	0.3904
04-05-2023	49.2530	V4-8	9.61	0.51	0.0668	0.1320
04-05-2023	49.2530	V4-9	10.83	0.02	0.0023	0.1537
04-05-2023	49.2530	V4-10	12.05	0.02	0.0035	0.2267

Appendix 6: Well panels with results

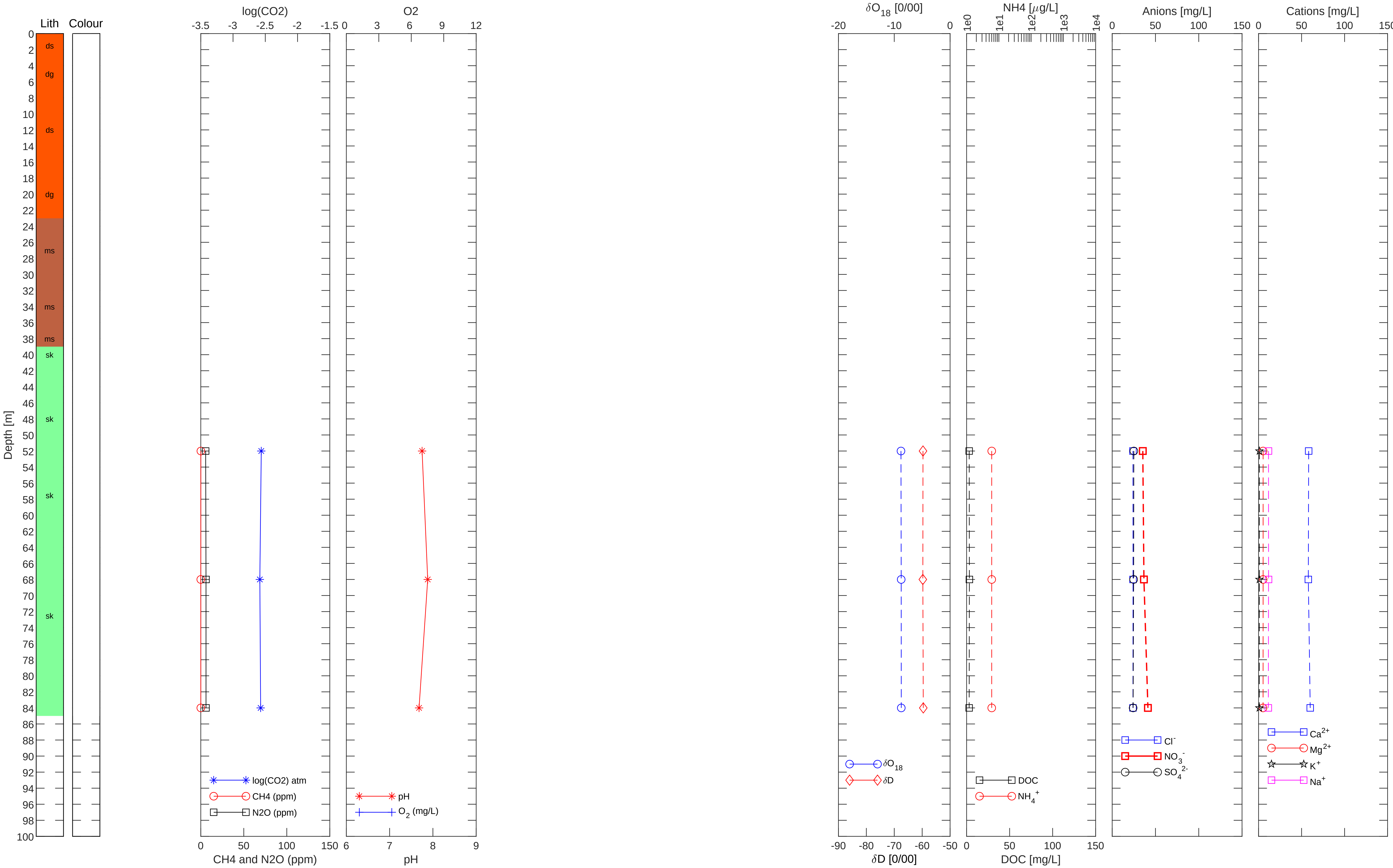
Villestrup Borehole existing well , DGUno 49. 378



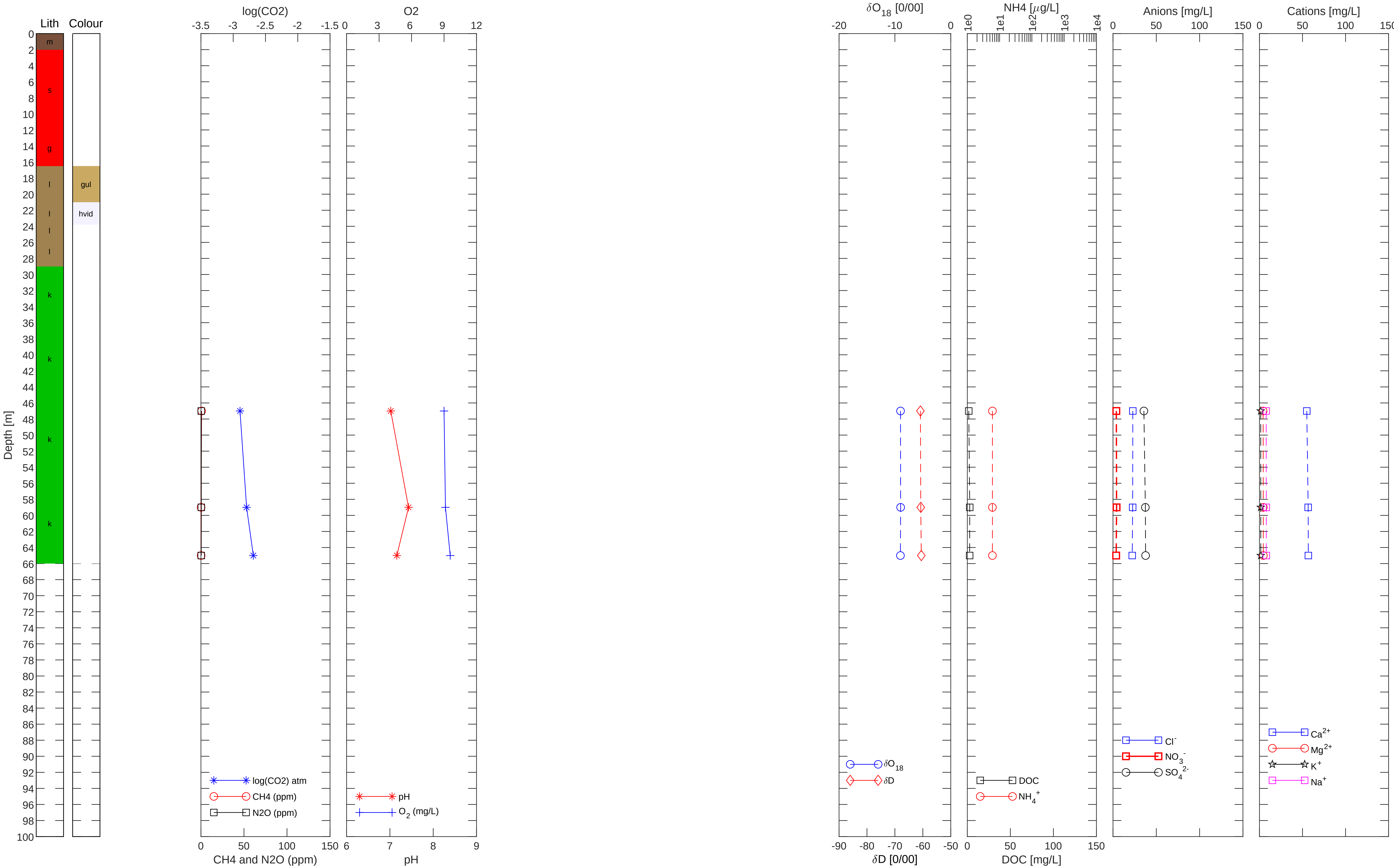
Villestrup Borehole existing well , DGUno 49. 385



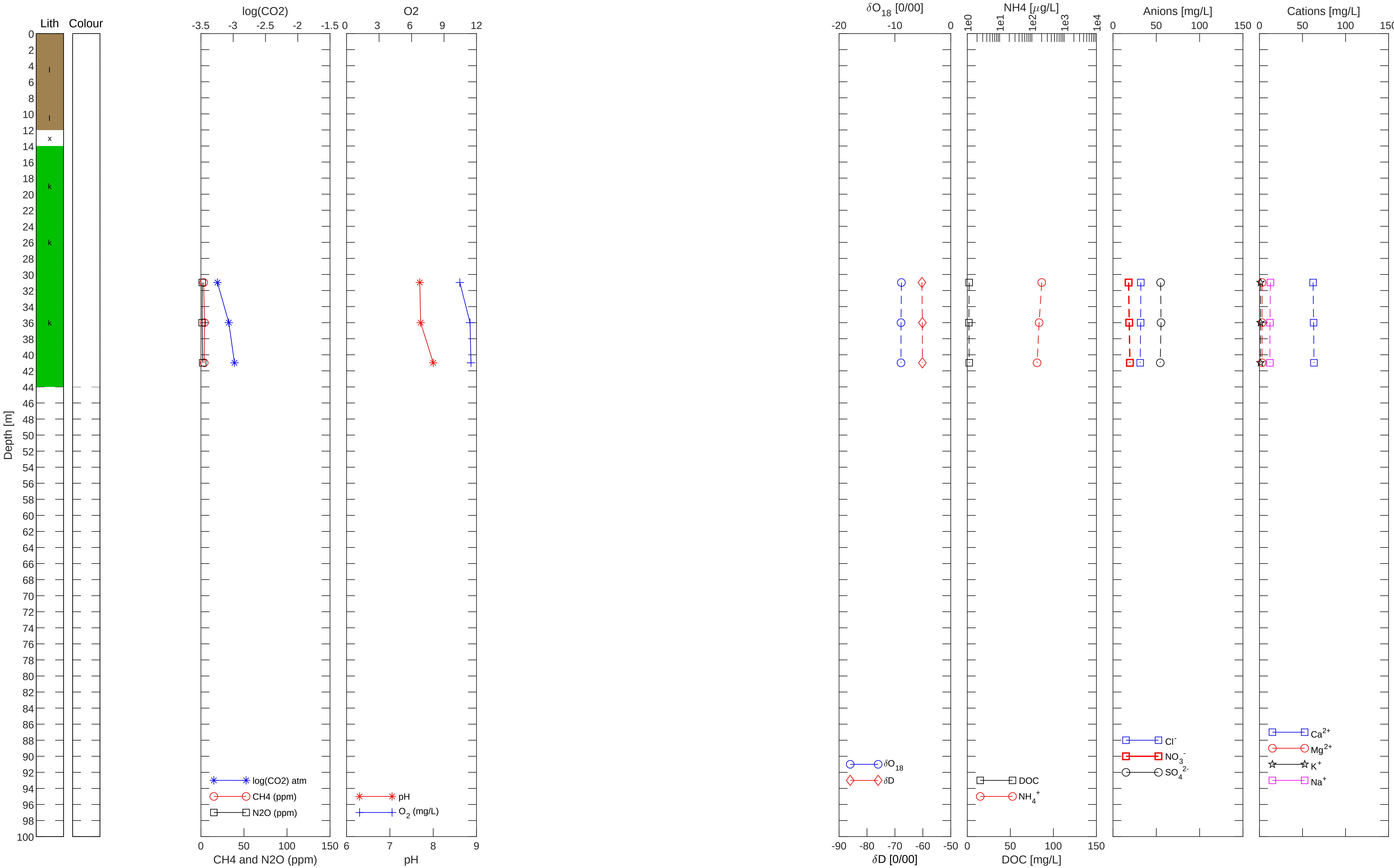
Villestrup Borehole existing well , DGUno 49. 386



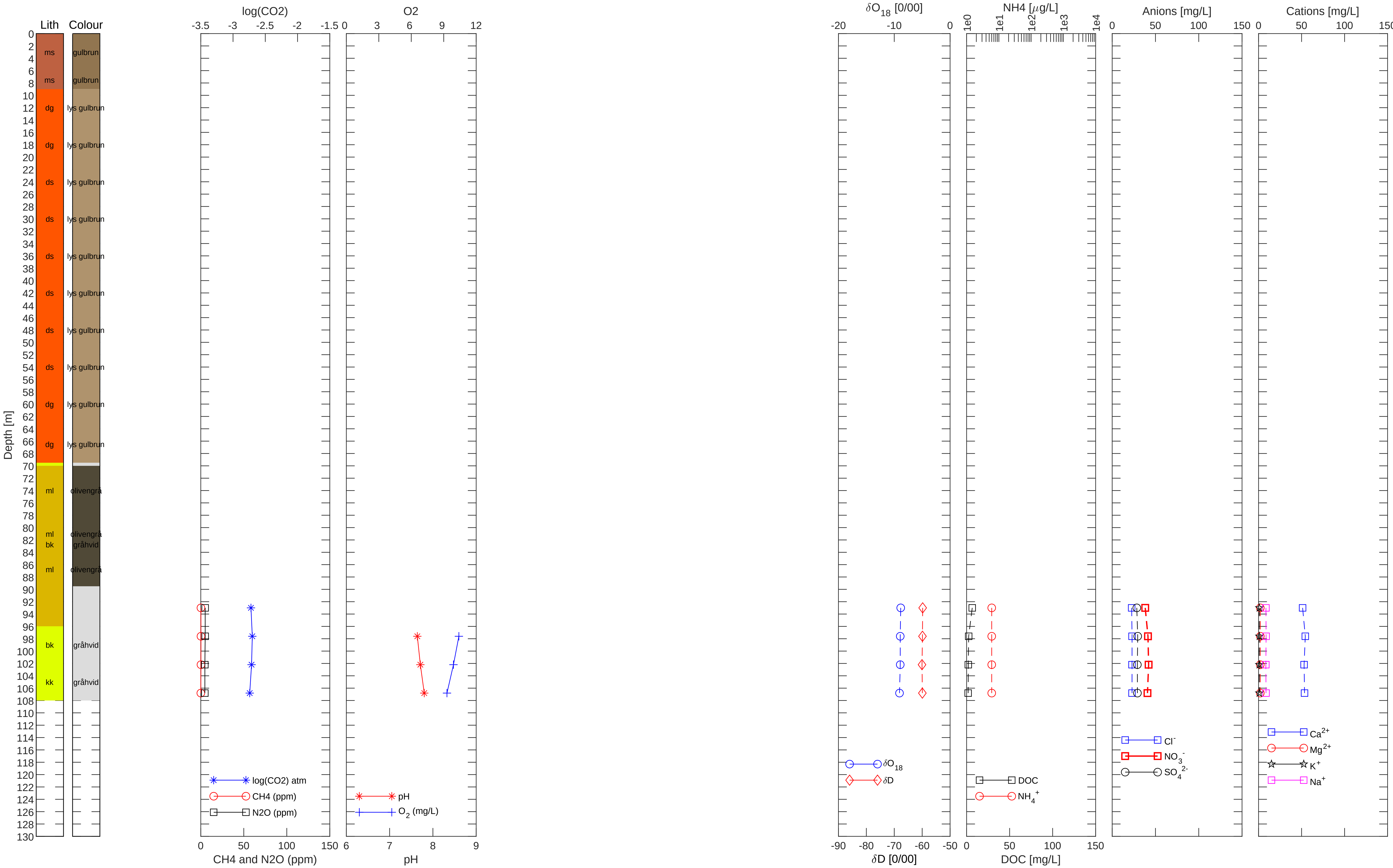
Villestrup Borehole existing well , DGUno 49. 448



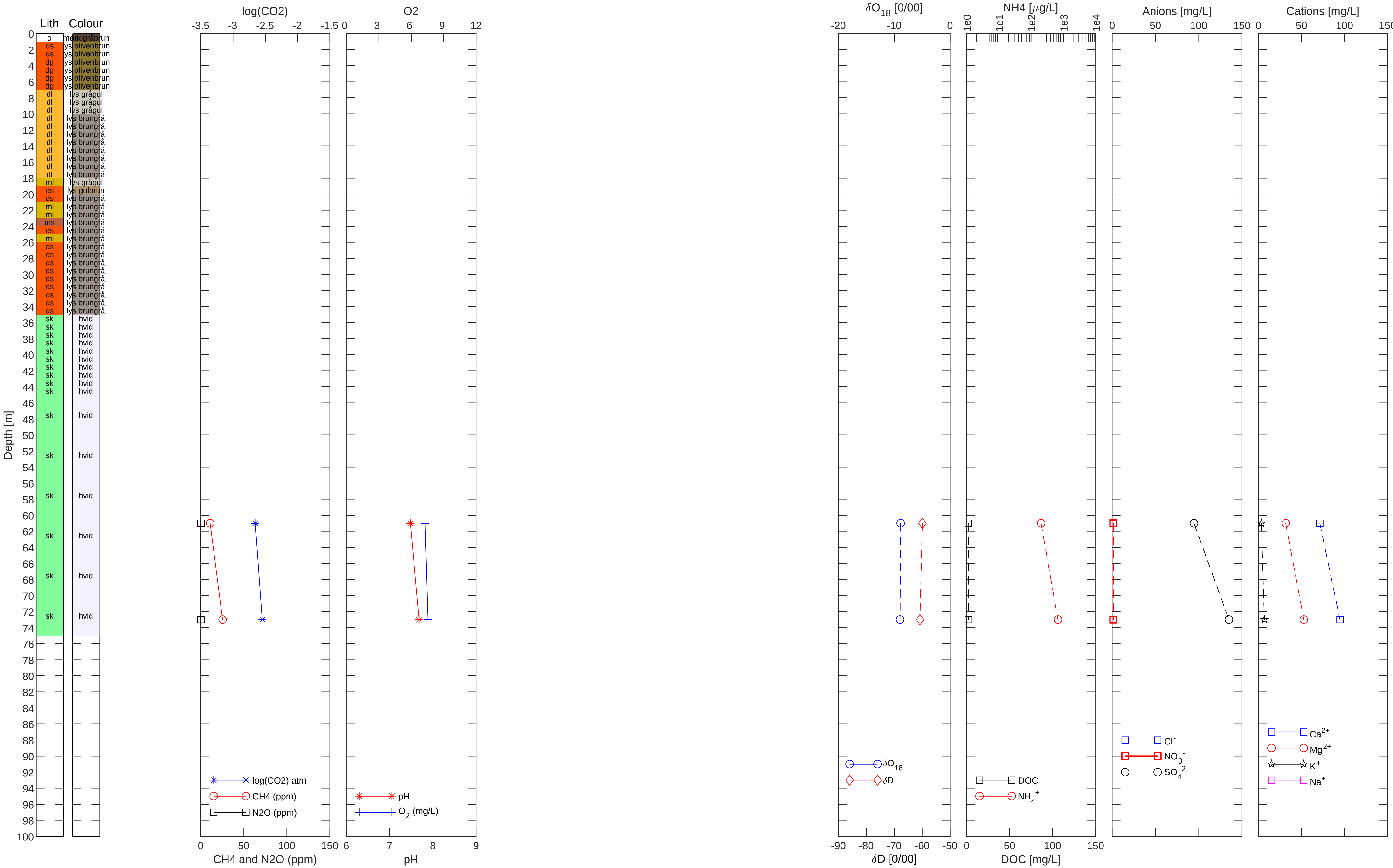
Villestrup Borehole existing well , DGUno 49. 594



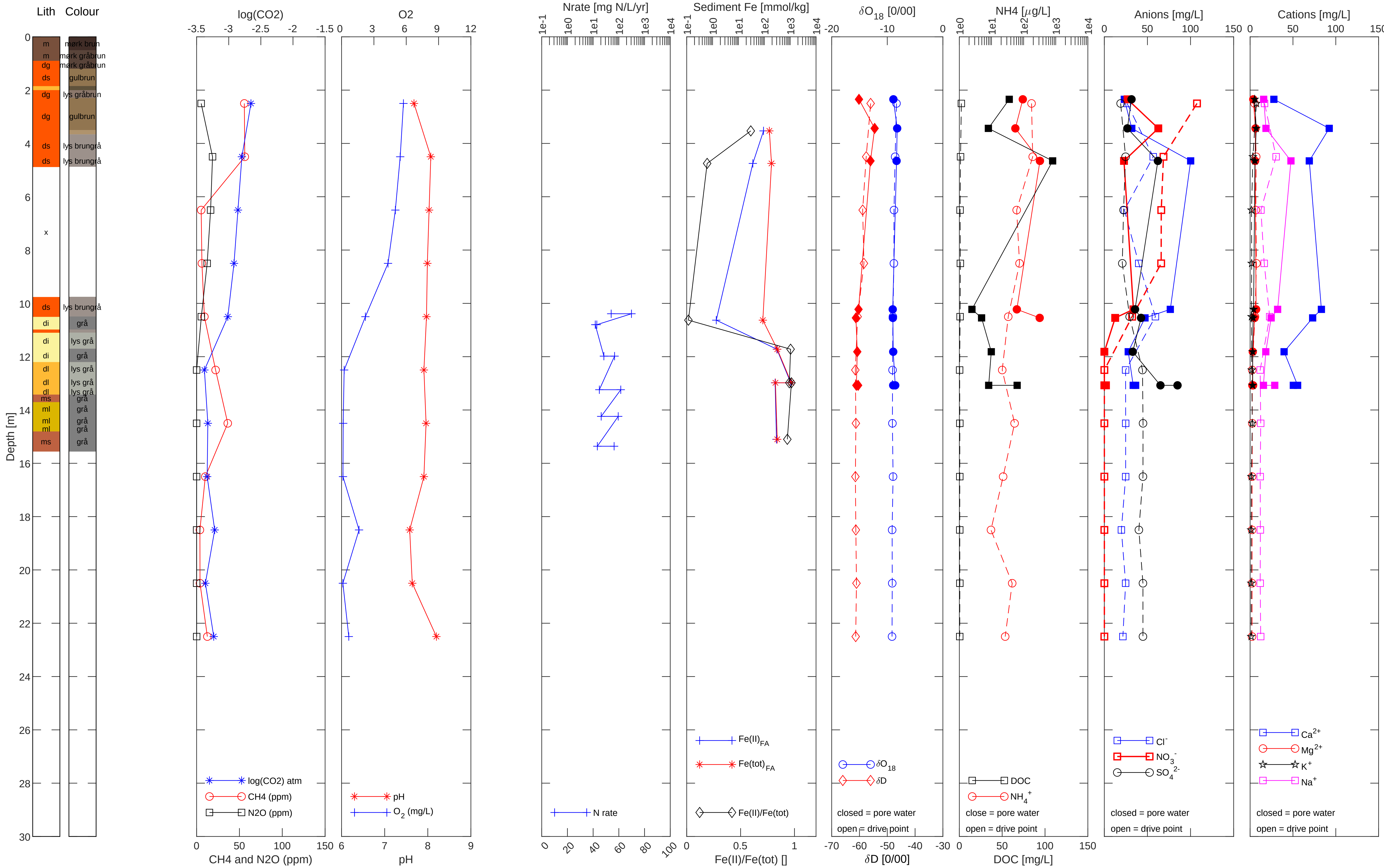
Villestrup Borehole existing well , DGUno 49. 965



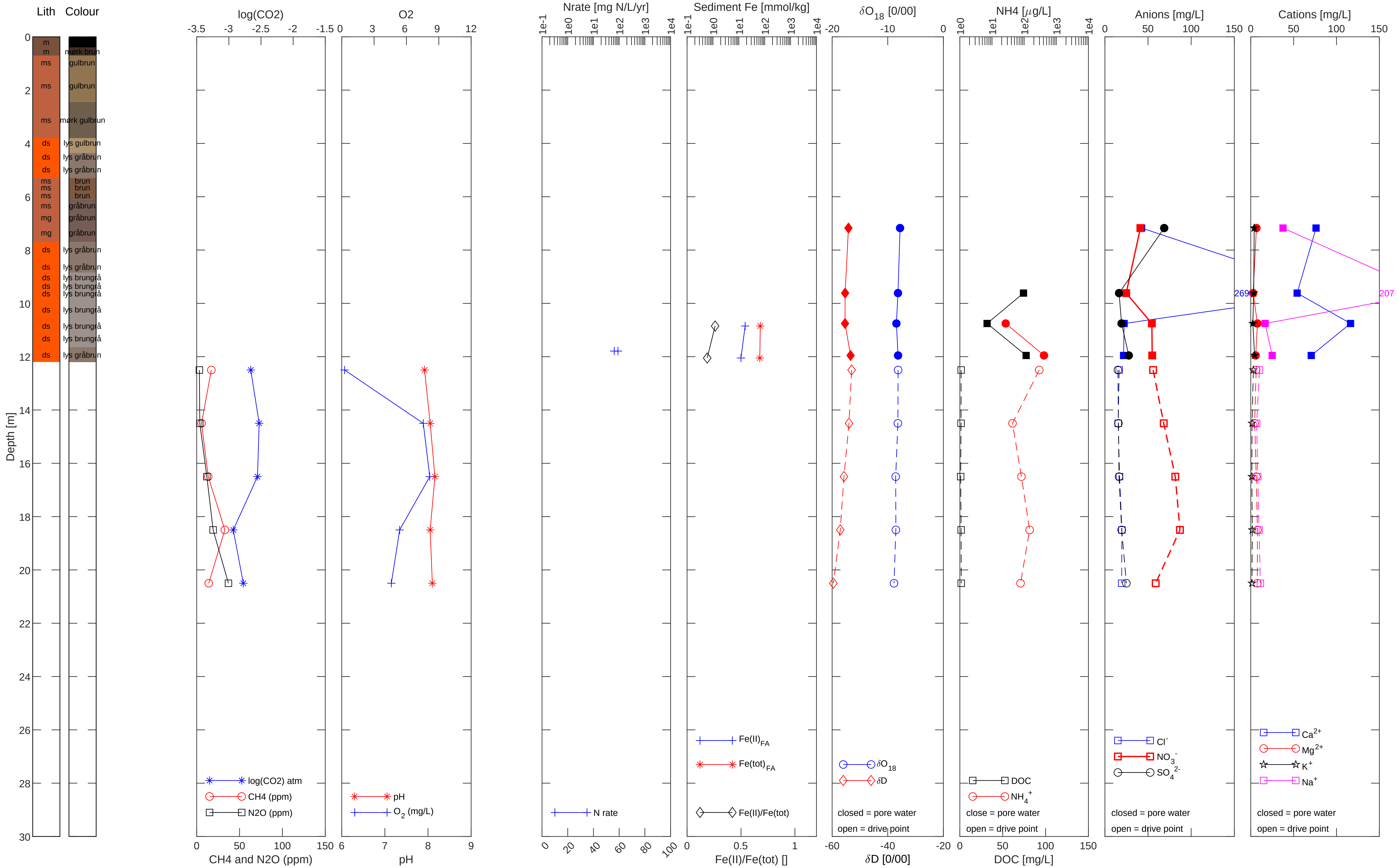
Villestrup Borehole existing well , DGUno 49. 1002



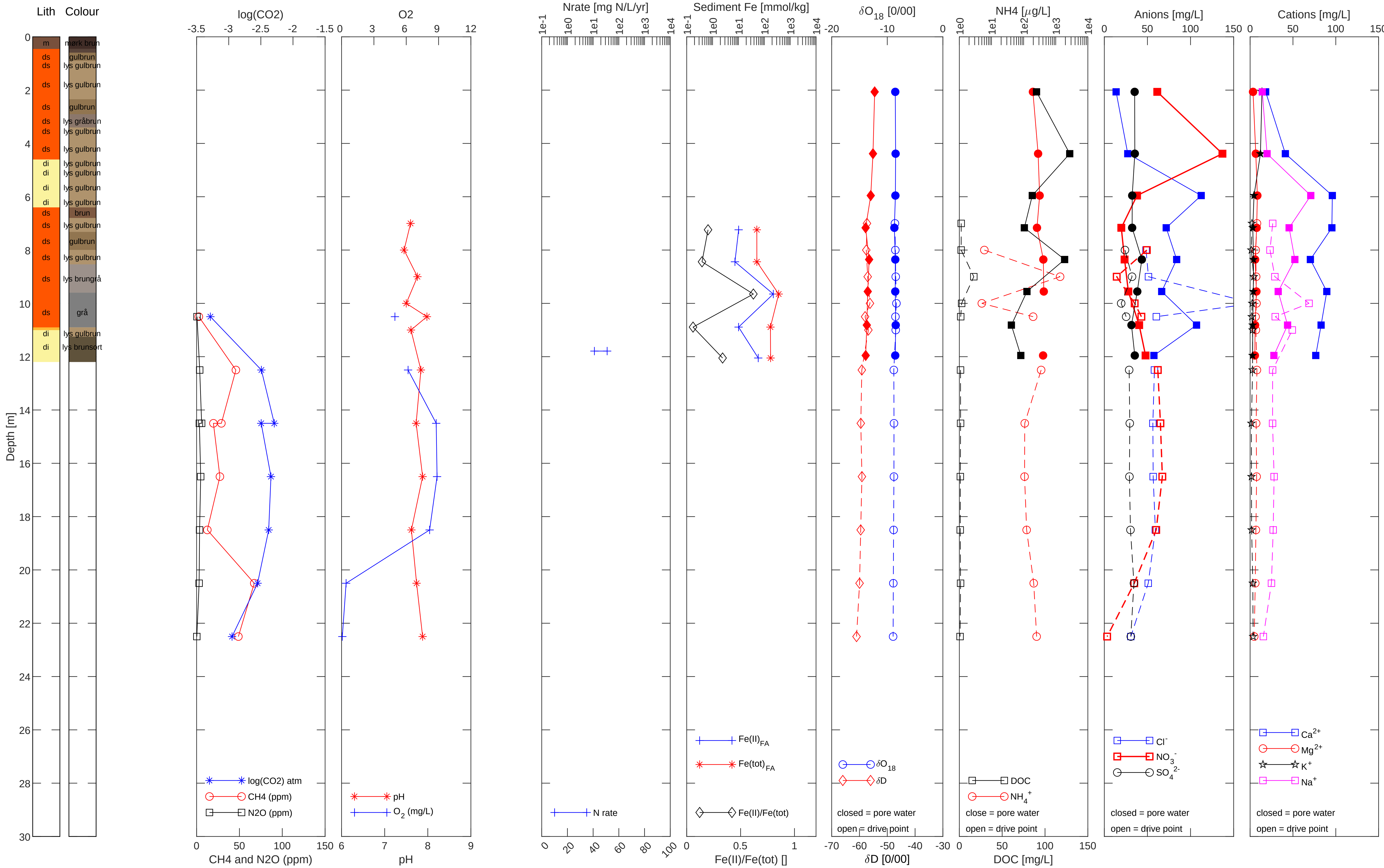
Villestrup Borehole V1 , DGUno 49. 2527



Villestrup Borehole V2 , DGUno 49. 2528



Villestrup Borehole V3 , DGUno 49. 2529



Villestrup Borehole V4 , DGUno 49. 2530