Electronic Supplement to: Vyse et al.,

S1: Supplementary text passages:

Text S1:

Retrieval of parameters from supraregional studies for comparison:

Information regarding sediment volumes, carbon pools and carbon accumulation rates were, where possible, extracted from literature sources in order to permit the supraregional comparison within this study. Extensive data for 31 Finnish lakes (sediment volumes, carbon pools and carbon accumulation rates) were retrieved from Pajunen (2000). Carbon accumulation rate data were extracted from Sobek et al., 2014 and Anderson et al., 2009 for 14 Greenlandic lake sites. 10 lake sites from Quebec, Canada were included from Ferland et al., 2012 where hydroacoustically derived sediment volume and carbon accumulation rates were available. Sediment volumes and carbon storage for 11 Alberta, Canada lakes were extracted from Campbell et al., 2000 alongside the carbon accumulation rate which was not provided for each individual lake location but as a mean across 191 lake basins. The global lake and reservoir dataset of Mendonça et al., 2017 was utilized to obtain carbon accumulation rates for 343 global lake sites (excluding reservoirs and wetlands not relevant for comparison within this study). Carbon accumulation rates for five locations at lake Baikal were obtained from Sobek et al., 2014 that were originally provided by Martin et al., 1998. Carbon accumulation rates were also derived from a study of 20 Siberian thermokarst lakes published in Anthony et al., 2014. For Uinta lake sites, sediment volume was estimated by combining lake surface areas and maximum core depths from provided supplementary data. The carbon amount of each Uinta lake site was also extracted from supplementary data. Sediment volumes and carbon pools were acquired from Thermokarst lakes, lagoons and Yedoma deposits from multiple studies from Alaska and Siberia (Jenrich et al., in review; Jongejans et al., 2018; Windirsch et al., 2020)

S2: Supplementary figures:

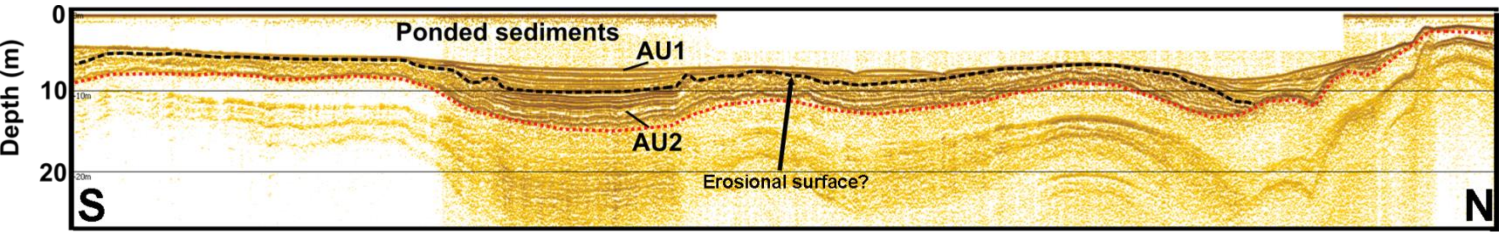

Figure S1. Hydro-acoustic profile from the northern-shelf demonstrating ponding of recent sediments belonging to AU1 alongside onlap and evidence of erosion of the underlying reflectors. This suggests some lake-level fluctuation that affected shallow regions at the lakes northern shelf.

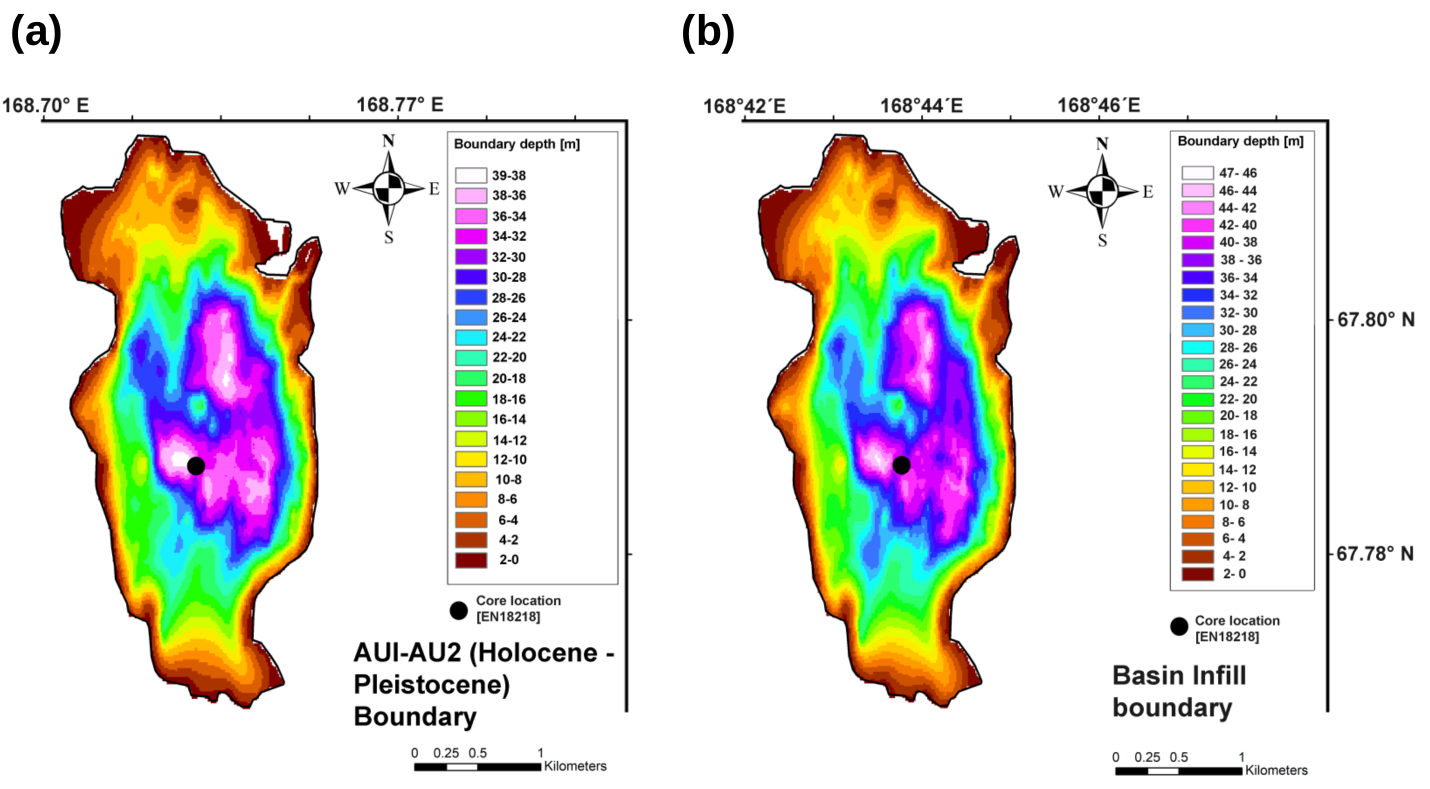

Figure S2. (a) Interpolated depths to the AU1/AU2 boundary that corresponds generally to the LUI/LUII (Holocene/Pleistocene) boundary. **(b)** Interpolated depth to the sediment base recorded within hydro-acoustic data at lake Rauchuagytgyn.

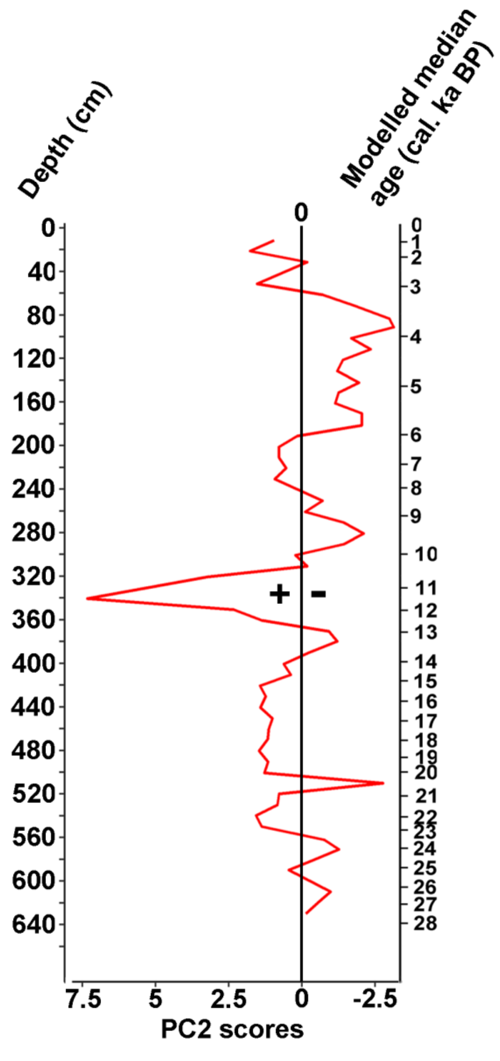

Figure S3. Stratigraphical plot of PC2 that explains 12.4% of the variance. The variation in PC2 scores shows similarity with the trends in mass accumulation rates observed in the core. More negative values generally reflect increased mass accumulation rates compared to more positive values that reflect reduced rates.

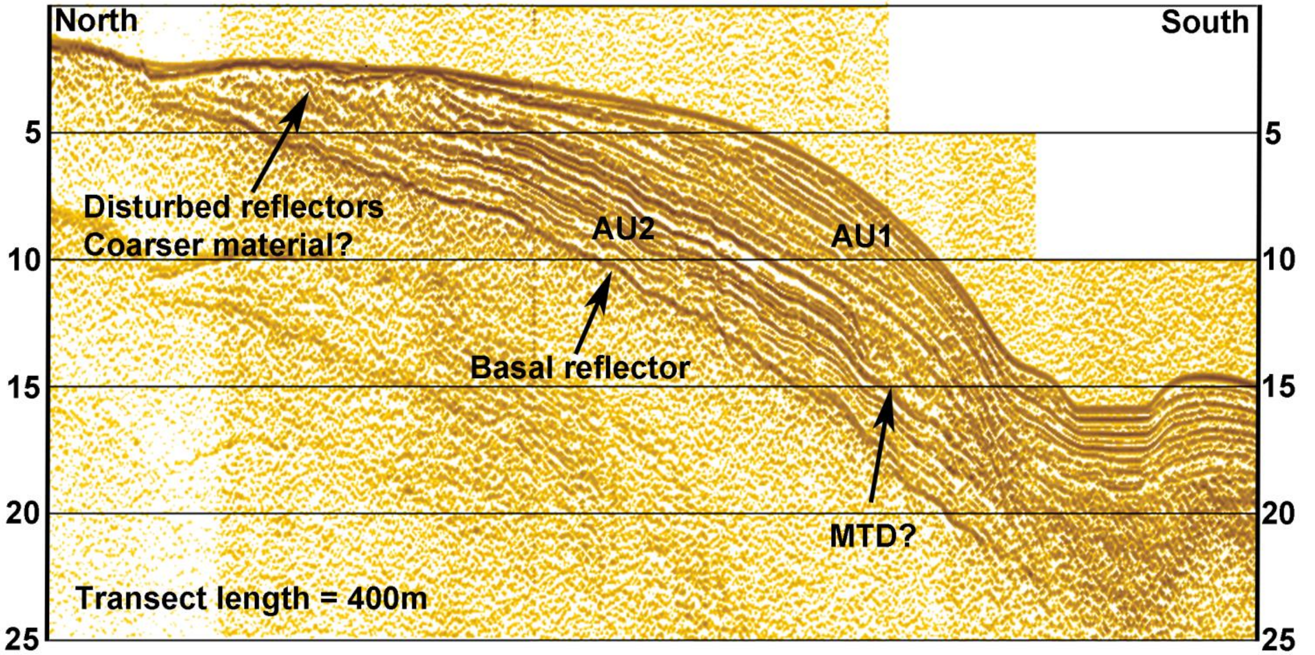

Figure S4. Zoomed image of thick sediment deposited at the transition between the northern Shelf and northern Sub-basin. Disturbed reflectors towards the north may reflect proximal coarse material derived from a northerly inflow, or reworking of sediments due to lake-level variability. A rhomboidal shaped deposit within AU2 may represent a mass transport deposit (MTD) from slope destabilisation.

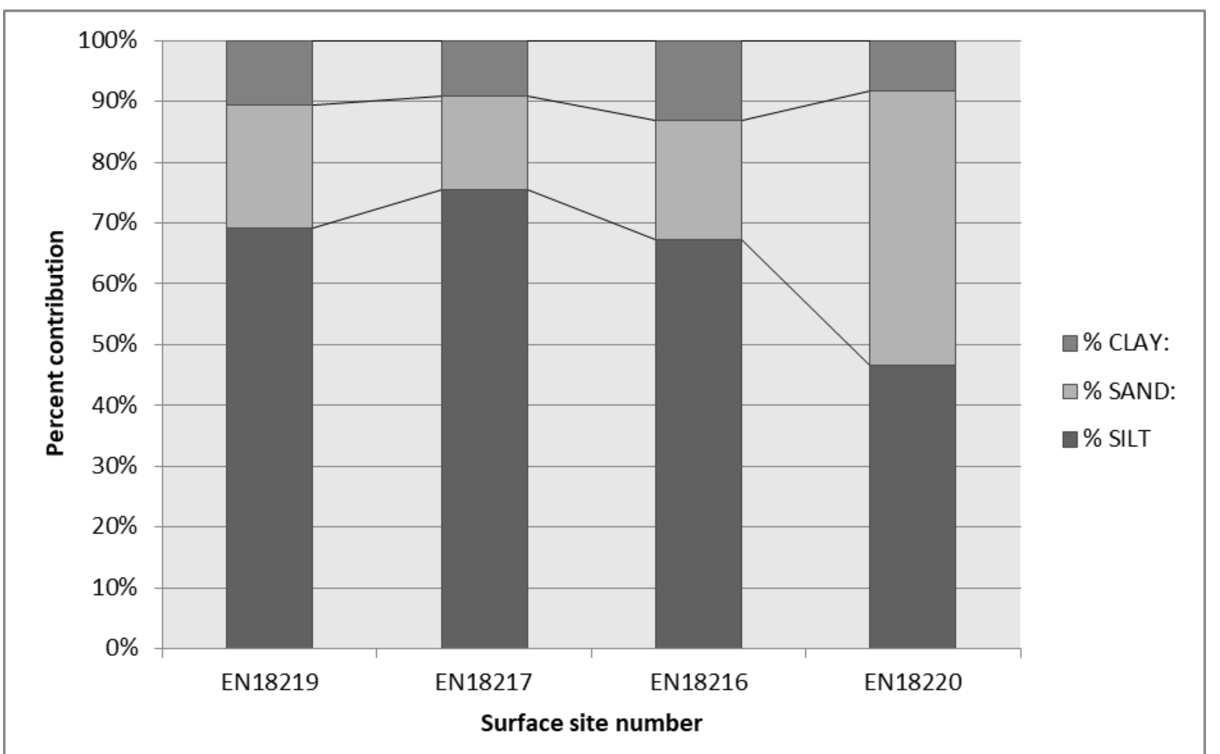

Figure S5. Percent contributions of clay, sand and silt to the grain-size distribution of surface samples collected at lake Rauchuagytgyn. Sample EN18220 represents a sample taken very close to the Gilbert type delta at the south-east lake margin. See figure 6 for a map of the sample locations.

Figure S6. Map of the Alluvial fan at the south-eastern lake margin. The upper alluvial fan shows erosional gullies. The alluvial fan possesses 2 major fluvial branches and numerous smaller branches that contribute coarse grained sediment to the south-eastern Sub-basin. (ESRI 2020)

S3: Supplementary tables:

Table S1. Hydrochemical parameters of the Epilimnion from Lake Rauchuagytgyn obtained from samples obtained during the 2018 expedition. * Values represent averages from three lake water surface locations (EN18216, EN18217, EN18220) shown in Fig. 1b in the manuscript.

Variable	Value*
Secchi depth (m)	3.9
DOC (mg/l)	0.89
Conductivity (us/cm)	85.5
pH	7.81
Temperature (°C)	7.9
Fluoride (mg/l)	< 0.05
Chloride (Mg/l)	0.81
Sulphate (Mg/l)	29.69
Bromide (Mg/l)	< 0.05
Nitrate (Mg/l)	0.51
Phosphate (Mg/l)	< 0.10
Al (ug/l)	< 100
Ba (ug/l)	< 20
Ca (mg/l)	12.0
Fe (ug/l)	< 100
K (mg/l)	0.31
Mg (mg/l)	1.98
Mn (ug/l)	< 20
Na (mg/l)	0.88
P (mg/l)	< 0.1
Si (mg/l)	1.35
Sr (ug/l)	61

S4: R code for Bootstrapping approach for pool calculations

This method is adapted from Jongejans et al., (2018) where it was applied to permafrost exposures from the Baldwin Peninsula, Alaska. The original code can be viewed here:
https://zenodo.org/record/3734247#.YBEcOuhKiUk

This approach is adapted here to permit the calculation of carbon and sediment Pools from lake sediments where no ice-wedges are present and hence this term has been excluded from the original script, to run in the R environment (R Core team, 2013).

```
#Required R packages "boot" & "Rcmdr"

library(boot)

library(Rcmdr)



setwd("YOUR WORKING DIRECTORY")

dir()
```

Calculations follow the following formulae that exclude ice wedges originally included by Jongejans et al., (2018):

  # OC pool [Mt] = (sediment_volume * DBD * (TOC/100))/10^6)

  # Sediment pool [Mt] = (sediment-volume * DBD)/10^6)

  # Sediment volume has the unit m^3, dry bulk density (DBD) in 10^3 kg m^{-3} or g cm^{-3},

  # Total organic carbon (TOC) content is reported in wt %

  # DBD and TOC/100 values are combined prior to being loaded into the script, as they are not independent, into the variable DBDTOC.

```
#Part 1: Script for OC pool calculation

### load data table with TOC*DBD values i.e. DBDTOC

DBDTOC <- read.table("XX.txt", header = TRUE)
```

Produce a dataframe with DBD and TOC including weight that compensates for uneven sampling intervals (See Jongejans et al., 2018 for details)

set parameter for sediment volume (m^3)

```
Vsediment <- XX   (for example 32990557 m^3)
```

Create an empty dataframe with combined DBD and TOC including a weight (for example: value that covers 20 cm occurs twice as often as a value that covers 10 cm)

```
out <- NULL
      for (i in 1:64){
        dbdtoc <- rep_len(DBDTOC$DBDTOC[i], length.out=DBDTOC$int[i])
        c <- data.frame(dbdtoc)
        out <-rbind(out, c)
      }

meanPool<-vector()   # Store mean values of 10,000 iterations
meanDensity<-vector()

## loop for 10,000 Bootstrap calculations
      for (i.R in 1:10000)
      {
        sampleDBDTOC <- sample(out$dbdtoc,20, replace = TRUE)
        samplebudget <- (Vsediment*(sampleDBDTOC/100))/1000000 # in Mt
        meanPool[i.R]<-mean(samplebudget)
        sampleTOCdensity<- (sampleDBDTOC/100)*1000 # in kg m-3
        meanDensity[i.R]<-mean(sampleTOCdensity)
      }
```

```
### Output statistics with example:
numSummary(meanBudget) # TOC pool (Mt)
     mean       sd    IQR      0%      25%      50%      75%     100%     n
 0.2590364 0.01976055 0.02676429 0.1709856 0.2458085 0.2594058 0.2725728 0.344778 10000
numSummary(meanDensity) # Volumetric OC pool (kg m-3)
    mean        sd     IQR    0%     25%  50%    75%   100%     n
 7.849587 0.5988044 0.811039 5.181382 7.448743 7.860781 8.259782 10.44782 10000


##Part 2: Script for Sediment pool calculation


#Almost identical treatment to Carbon pool calculation
#TOC term is however excluded and the DBD is just utilized


DBDMASS <- read.table("XX.txt", header = TRUE)


### set parameter for sediment volume (m3)
     Vsediment <- XX (for example 32990557 m3)


  out <- NULL
            for (i in 1:64){
              DBD <- rep_len(DBDMASS$BDMASS[i], length.out=DBDMASS$int[i])
              c <- data.frame(DBD)
              out <-rbind(out, c)
            }


meanPool<-vector()
meanDensity<-vector()
```

```
## loop for 10,000 Bootstrap calculations

        for (i.R in 1:10000)

        {

          sampleDBD <- sample(out$DBD, 20, replace = TRUE)

          samplebudget <- (Vsediment*(sampleDBD))/1000000 # in Mt

          meanPool[i.R]<-mean(samplebudget)

          sampledensity<- (sampleDBD)*1000 # in kg m-3

          meanDensity[i.R]<-mean(sampledensity)

        }

########################################End of Script##########################################
```

S5: References used in the supplementary material

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