Sediment Provenance and Weathering in Kongressvatnet, Western Spitsbergen, Svalbard

Maya Wei-Haas (mweihaas@smith.edu) and Robert Newton
Department of Geology, Smith College, Northampton, MA 01063

Introduction

This study focuses on major and trace element chemistry as proxies for sediment provenance of a small glacial lake, Kongressvatnet, located in Western Spitsbergen, Svalbard (Figure 1).

Figure 1: Location of study site in Spitsbergen, Svalbard (black star). Image from the Norsk Polar Instituitt.

The focus of this study, Kongressvanet, is an oligotrophic, meromictic lake that is stabilized by sulfur-rich mineral springs entering from the Northern shore of the lake (Bøyum and Kjensmo, 1970). During the 2006 field season, the surface area was approximately 0.82 hectare with a maximum depth of 52m. The lake is both thermally and chemically stratified and has a distinct summer thermocline at approximately 10m and a chemocline at approximately 44m depth.

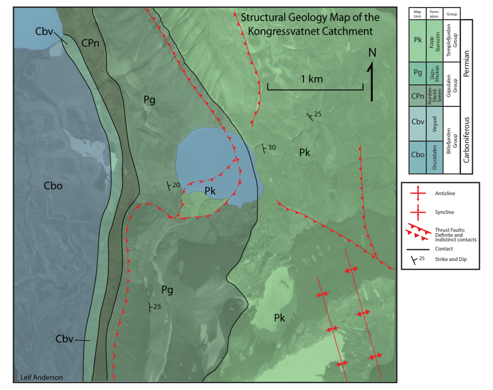
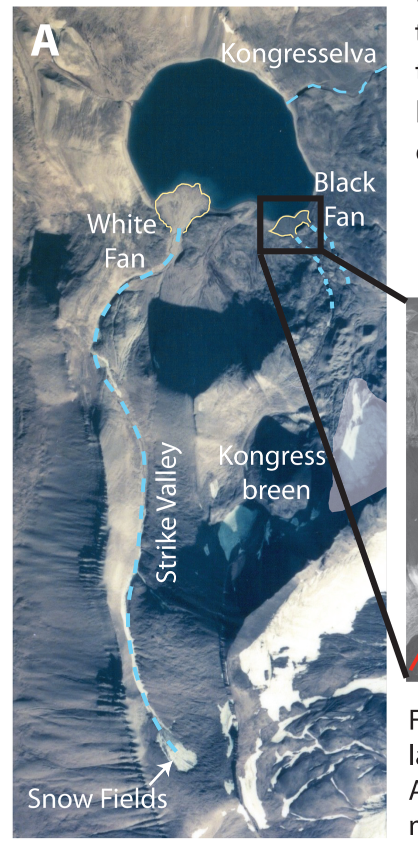


Figure 2: Geology of the Kongressvatnet catchment (from Anderson, 2007).

The Kongressvatnet catchment lends itself to provenance studies since there are two distinctly different alluvial fans across which most of the water enters the lake. The White Fan is covered by alluvial sediments derived from the dolomitic Gipshuken Formation and is fed by meltwaters from permanent snowfields at the top of the Strike Valley (Figure 2 and 3). The Black Fan is composed of the Permian Kapp Starostin Formation, a glauconitic sandstone with subordinate limestone (Figure 2). This fan has little source area as it is positioned immediately adjacent to the drainage divide between Kongressdalen and Grønfjord. During the peak of the Little Ice Age, Kongressbreen likely advanced to abut this divide, allowing meltwater to transport Permian Kapp Starostin Fm. rocks to form the Black Fan (Anderson, 2007) (Figure 3). This suggests that provenance of Kongressvatnet sediment may reflect Late Holocene glacial movements.



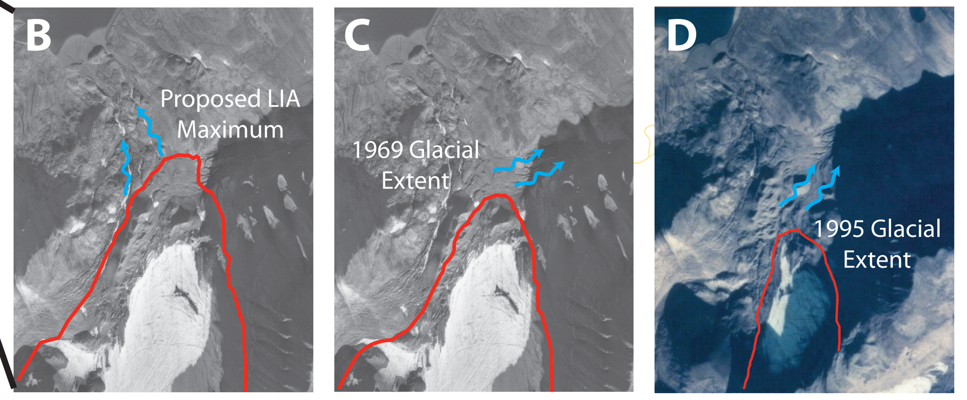


Figure 3: A) Aerial photograph of Kongressvatnet, with the inlet and outlets labeled. B) Maximum glacial extent when meltwater fed the Black Fan (from Anderson, 2007). C, D) Reduced glacial extent, resulting in the redirection of meltwater toward Grønfjord (aerial photographs from Norsk Polar Instituitt).

Methods

Samples were collected during July and August of 2008 as part of the Svalbard Research Experience for Undergraduates. One sediment core was collected at 49m depth near the center of the lake. Surficial sediment samples were collected at 32 sites along both transverse and axial transects across the two fans (Figure 4). The core was analyzed using the following methods:

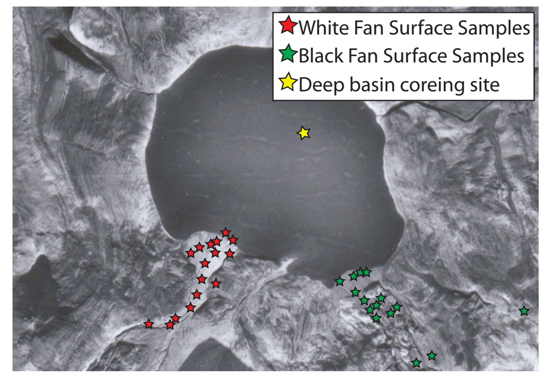


Figure 4: Location of sampling sites.

- ✓ ***ITRAX Scanning X-Ray Fluorescence*** - relative major and trace element compositions at 0.5mm increments
- ✓ ***Scanning Electron Microscopy*** - grain morphology of Pd-Au coated core samples

The core was sub-sampled at five different depths. These samples in addition to 8 Black Fan and 6 White Fan surface sediment samples were analyzed using the following methods:

- ✓ ***X-Ray Fluorescence*** - major and trace element composition using the fused glass disc and pressed pellet methods respectively
- ✓ ***X-Ray Diffractometry*** - clay mineralogy of oriented clay mounts using the following treatments: air-dried, ethylene glycol, 375°C and 550°C ignition, K/Mg-saturation, and glycerol saturation (Moore and Reynolds, 1997).

Sediment Provenance

X-Ray Fluorescence analysis of the White and Black Fan surface sediments reveals distinct chemical compositions, suggesting that the core sediment chemistry should reflect source area. Unexpectedly, the 5 samples collected from the core (red stars, right) reveal a chemical composition that resembles only that of the White Fan sediment, indicating a negligible Black Fan input into Kongressvatnet (Figure 5).

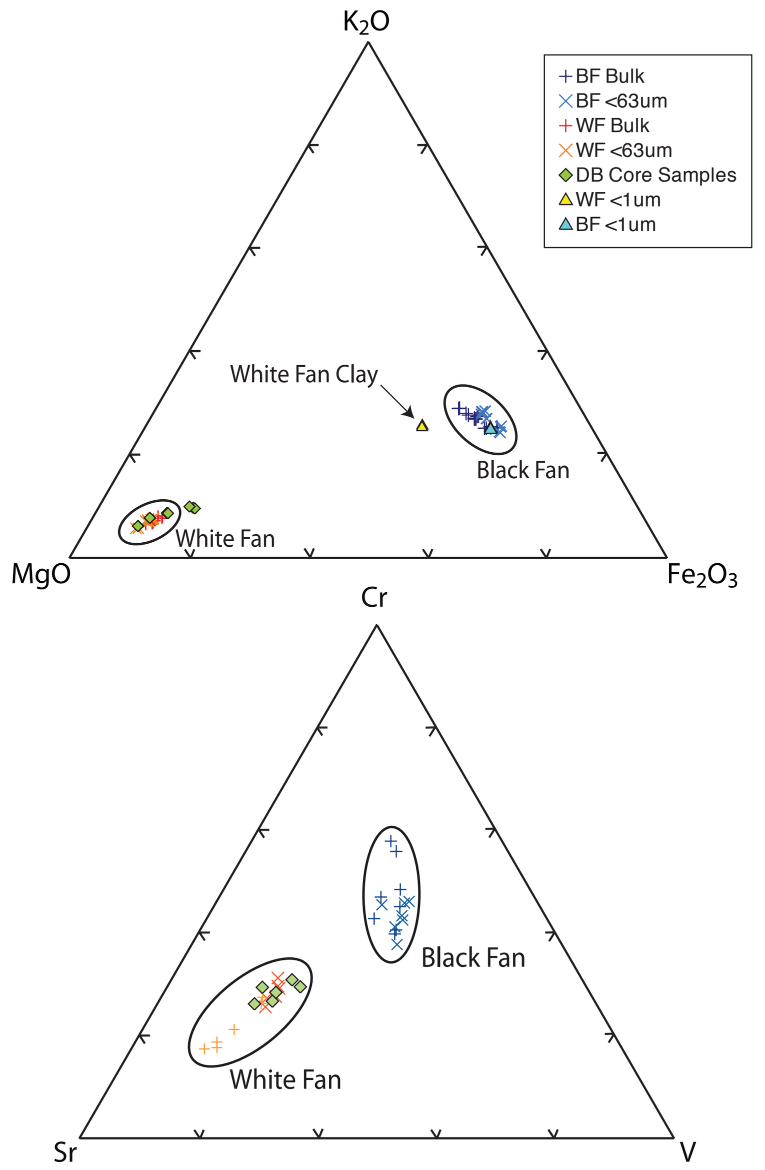
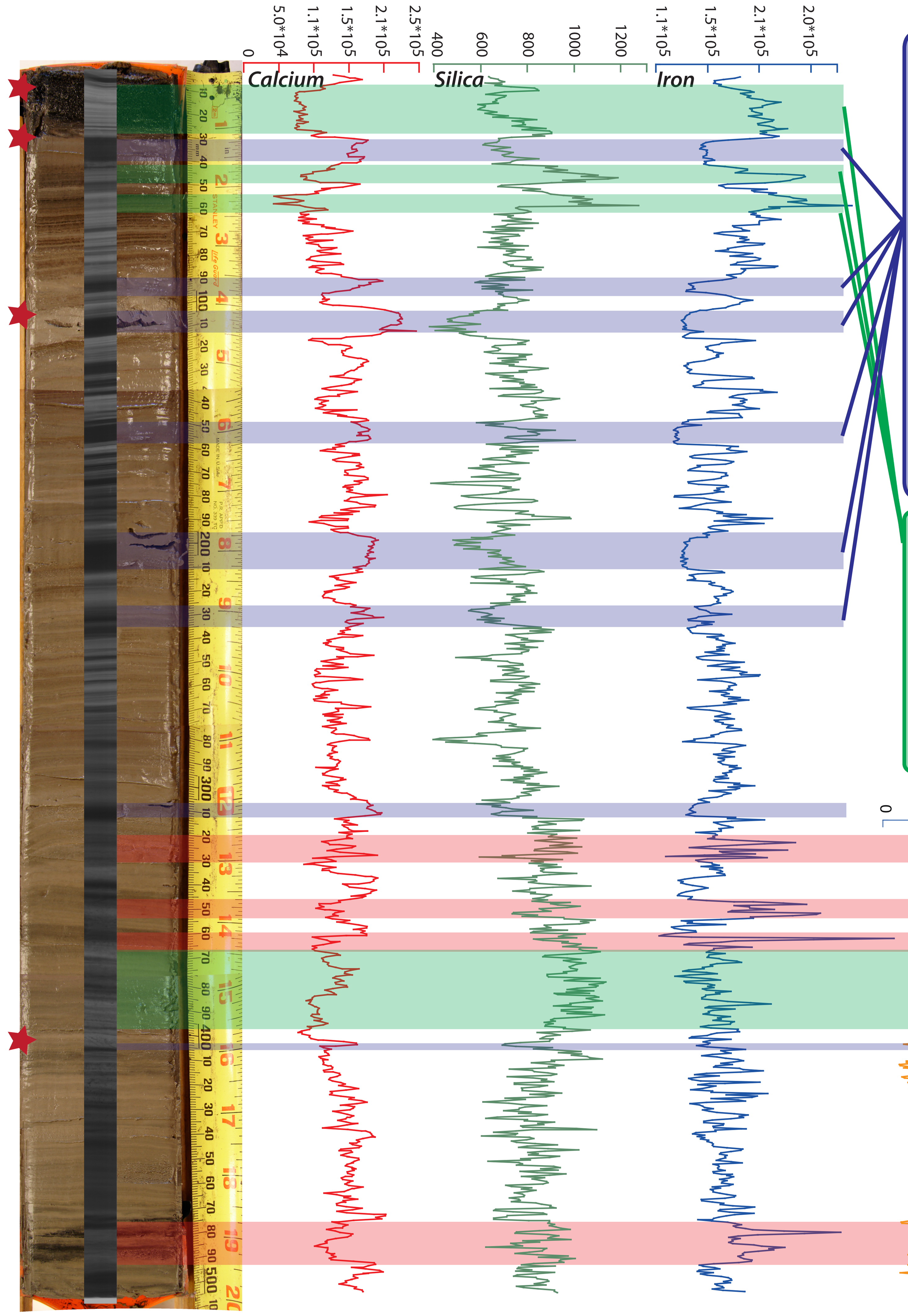
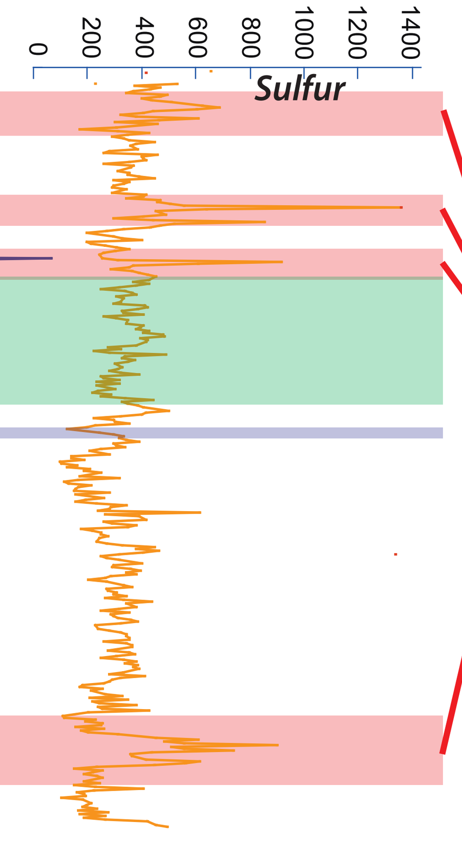


Figure 5: Ternary plots of select major and trace element compositions for the Black Fan (blue), White Fan (red and orange), and core (green) sediments, demonstrating the unique chemical compositions of the fan sediments and the White Fan dominated core chemistry.





The sections highlighted in blue are select regions of the core that display high density, high calcium, and low silica. These regions likely reflect periods of calcite precipitation, which is further supported by the supersaturation of Kongressvatnet waters in calcium with respect to calcite (Figure 6). SEM analysis of the core sediments reveals the presence of sharp-edged rhombohedra and fibrous needles, suggest the presence of non-detrital sediments (Figure 7).

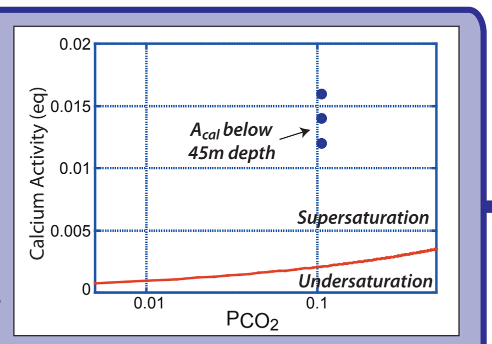


Figure 6: Calcite equilibrium diagram, calculated at 3°C. Kongress water chemistry plotted as blue points.

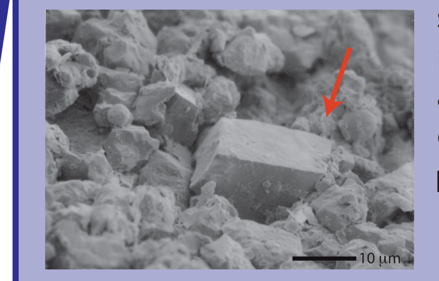


Figure 7: An euhedral rhomb, suggesting calcite precipitation (red arrow).

Possible reasons for calcite precipitation:

1) Increased biologic activity as a mediator for precipitation
2) Elevated calcium concentrations due to prolonged cold periods and/or anomalous ice thickness (Diagram right).

The green highlighted regions indicate high silica, low density, and low calcium sediments. These sections may reflect periods of limited calcite precipitation and/or periods of calcite dissolution. SEM analysis supports both hypotheses; sections of the core lack sharp-edged euhegral grains and other regions contain euhedral rhombs, with significant dissolution (Figure 8). These sections may represent warm periods in which organic acids were produced due to increased organic input and decomposition (Diagram right).

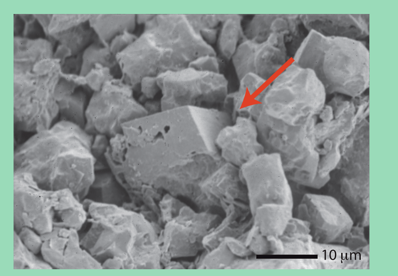


Figure 8: An euhedral rhomb displaying significant dissolution (red arrow).

Iron correlates strongly with silica throughout the core, suggesting the presence of iron is related to detrital sediments such as illite and glauconite.

The red highlights to the left, mark notable peaks in iron that do not correlate with silica, but with sulfur. These peaks suggest the reduction and precipitation of iron in the form of iron sulfides (Figure 9).

Iron reduction may result from increased organic matter input during warm periods (Diagram right).

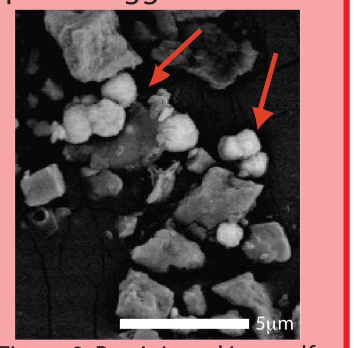


Figure 9: Precipitated iron sulfur framboids as a result of reducing conditions (red arrows). From Guillizzoni et al. (2001).

Black Fan Weathering

Clay samples from the meltwater channels and the Kapp Starostin rocks contain illite/glauconite clays (Figure 10 and 11). However, material from the debris flows between the primary channels reveal significant weathering, as evidenced by the mobilization of potassium and the formation of vermiculite (Figure 12 and 13). The weathered clays may indicate an early period of Kapp Starostin Fm. deposition subsequently eroded by the meltwaters from Kongressbreen during the Little Ice Age or an overall older age for the Black Fan formation.

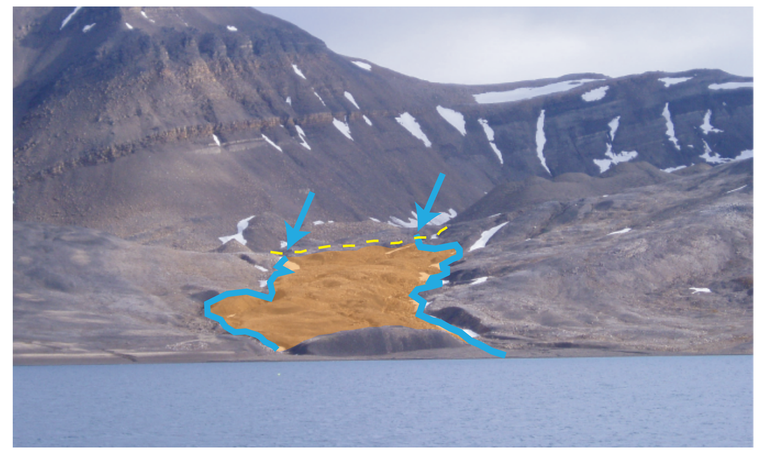


Figure 10: Image of the Black Fan as seen from the North shore of the lake. Samples were collected from the two primary channels (blue tracing) and the debris flow lobes between the two channels (orange shading). The proposed LIA maximum is labeled (yellow dashed line) (Anderson, 2007).

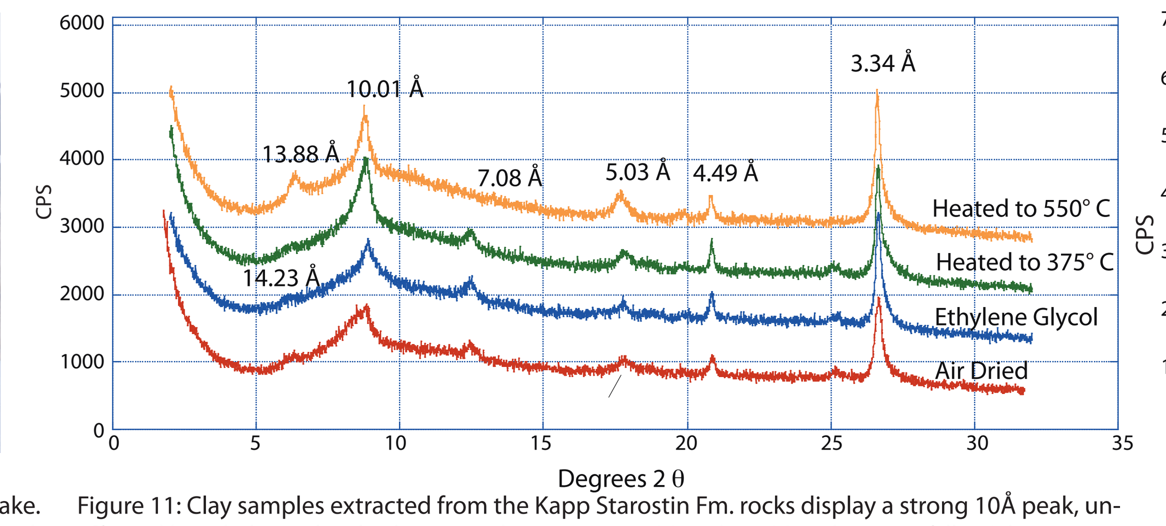


Figure 11: Clay samples extracted from the Kapp Starostin Fm. rocks display a strong 10Å peak, unaffected by ethylene glycol solvation or heating to 375°C and 550°C, indicative of illite/glauconite clay (Moore and Reynolds, 1997). Samples collected from the freshly exposed channels display similar XRD spectra.

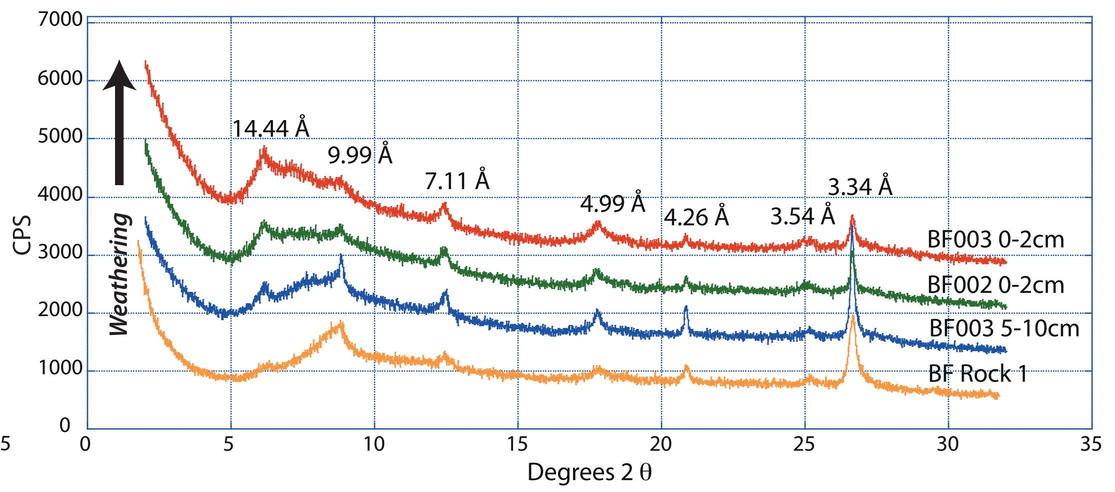


Figure 12: Samples collected from vegetated debris flows between the meltwater channels reveal a diminished 10Å phase and a slightly expandable peak at approximately 14Å, unaffected by magnesium and glycerol saturation (d 060 of 1.54Å), indicative of vermiculite (Moore and Reynolds, 1997). The inverse relationship between these peaks reflects the weathering of illite to vermiculite.

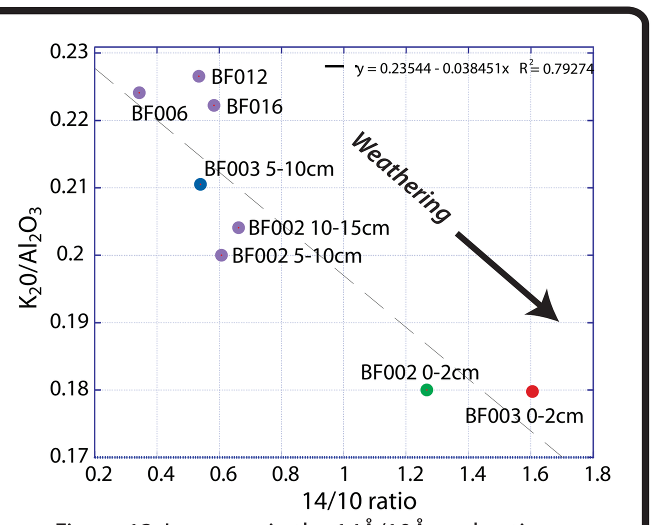
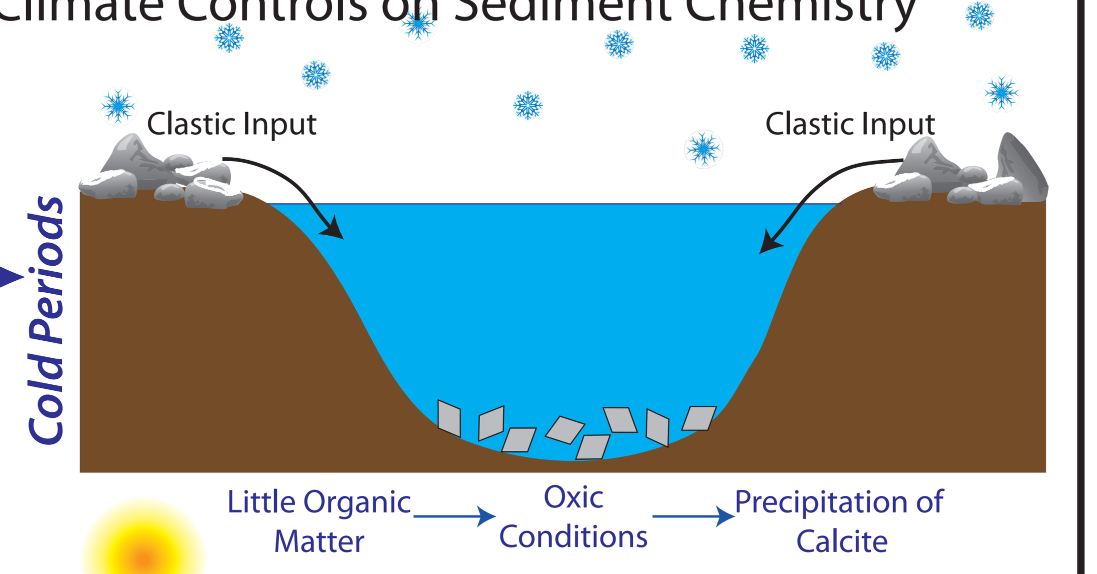
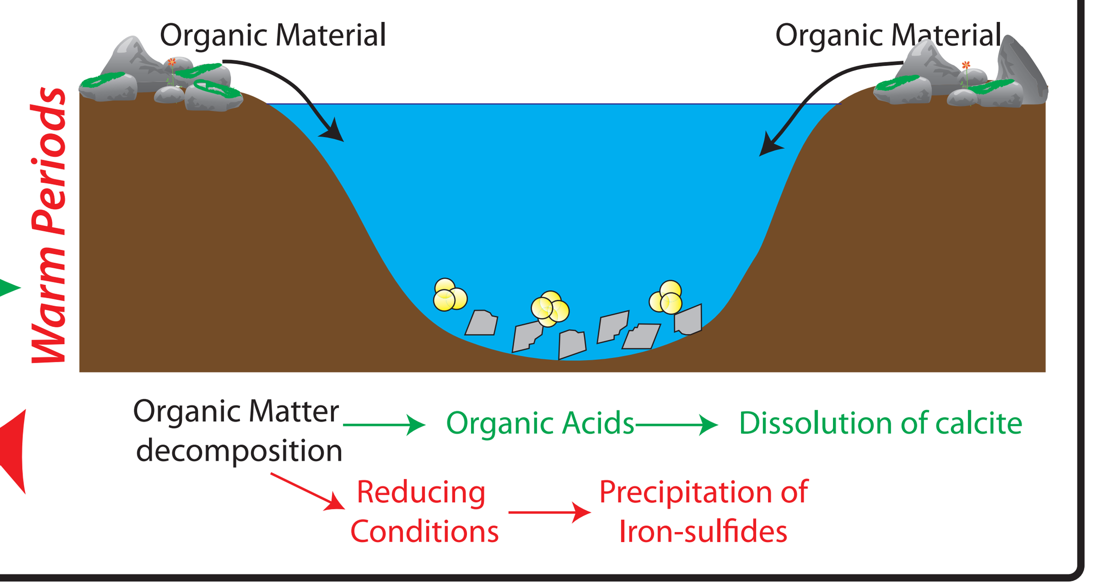


Figure 13: Increases in the 14Å/10Å peak ratios correspond to decreasing K/Al_2O_3 ratios in the weathered sediments (colors correspond to samples in Figure 12).

Climate Controls on Sediment Chemistry





Conclusions

- The core sediments lack the Black Fan chemical signature. Possibilities that may account for the absence of Black Fan material:
  - A significantly older glacial advance (Pre-Little Ice Age) formed the Black Fan, which is supported by the presence of highly weathered debris flows.
  - Kongressbreen is a cold-based glacier and therefore did not produce fine glacial flour from scouring of bedrock.
- Changes in water chemistry rather than provenance account for chemical variations in core sediments. Examples inlude the following:
  - Periods of high calcium may represent precipitation of calcite during cold periods. Lower temperatures may increase ice thickness and concentrate calcium in the remaining lake water.
  - Warmer climate results in increased vegetation and the input of organic matter. Decomposition of organics causes reducing conditions and the precipitation of iron sulfides. This decomposition additionally produces organic acids, which may dissolve calcite.

Future Research

- Due to the presence of carbonates and coal in the catchment, dating of sediments is extremely difficult. Advances in tephra calibration and paleomagnetics are promising methods to provide constraints on sediment age (Benjamin Schupack, Univ. Colo. Boulder, personal communication).
- Detailed SEM analysis of sediment grain morphology and coulter counter measurement of grain size for the core sediments would aid in the interpretation of elemental data from scanning XRF.

References
Anderson, L. "Surficial Geology of the Kongressvatnet catchment, Svalbard, Norway." Honors Thesis, Montana State University (2007): 1-76.
Bøyum, A., and J. Kjensmo. "Kongressvatn. A creogenic meromictic lake at Western Spitsbergen." Arch. Hydrobiol 67.4 (1970): 543-552.
Guilizzoni, P., A. Marchetto, A. Lami, A. Brauer, L. Vigliotti, S. Musazzi, L. Langone, M. Manca, F. Lucchini, N. Calanchi, E. Dinelli, and A. Mordenti. "Records of Environmental and Climatic Changes during the Late Holocene from Svalbard: Palaeolimnology of Kongressvatnet." Journal of Paleolimnology 36.4 (2006): 325-51.
Moore, D. and R.C. Reynolds, Jr., 1997, X-Ray Diffraction and the Identification and Analysis of Clay Minerals, 2nd ed.: Oxford University Press, New York.
Norsk Polar Instituitt. 01/2007. Norsk Polar Instituitt. 20 Mar 2009 <http://npiweb.npolar.no/>.

Acknowledgments
This project would not be possible without the support from the Univ. in Svalbard and the Svalbard Research Experience for Undergraduates and my REU advisors: Al Werner, Mike Retelle, and Steve Roof; thanks to Erik Brown and Marian Kramer from the Scanning XRF facility at the Univ. of Minnesota, Duluth; Mike Rhodes and Mike Vollinger from the X-Ray Fluorescence lab at the Univ. of Massachusetts; and the support from the Mellon Mays Foundation and the Smith College Geology Department.