**Abstract:**

Holocene sediment infill from glacier-fed Cariboo Lake was examined using a 10 khz acoustic sub-bottom profiler and surficial sediment cores up to 4 m in length. Sediment influx into Cariboo Lake is dominated by annually laminated silt and clay sediments delivered primarily by overflow currents of suspended clastic sediments produced in the glaciated headwaters. The sediment infill is estimated to be ~ 18 m thick and can be broken into two main sediment facies. The lower facies (facies A) is poorly laminated and indicates reduced headwater flow and sediment infill. The upper facies (facies B) is acoustically laminated suggesting increased inflow to Cariboo Lake and the occurrence of turbidity deposits. Sediment cores were retrieved from the upper portion of facies A and provided evidence that inflow of clastic sediment to Cariboo Lake remained high enough to produce annual varves over the past two millennia. An average sediment accumulation rate of 2 mm/yr was calculated from two of the dated sediment cores. Based on this sediment accumulation rate the ~ 18 m sediment package is estimated to be representative of 9000 yr BP.

The lower layer coincides with the Northgrippian period (8300 – 4200 BP) which consisted of high temperatures and reduced glacier cover.

**Introduction:**

Sediment collected from glacier-fed lakes have the potential to hold a long-term archive of environmental change. Various environmental conditions that control the production, transfer, and storage of sediment in glaciated watersheds determine the total flux of sediment that enters a lake (e.g. Leonard & Reasoner, 1999; Heideman, Menounos, & Clague, 2017). The transfer of sediment through a watershed can be quantified as specific sediment yield, which is the amount of sediment that leaves a catchment over a given time period and is expressed as a mass per unit area per unit time (Onstad, 1984; Heideman et al., 2017). Variations in specific sediment yield has been linked to changes in glacier extent (Menounos, Koch, Osborn, Clague, & Mazzucchi, 2004; Hodder, Desloges, & Gilbert, 2006), geomorphic and hydrologic events (Desloges & Gilbert, 1994a, 1994b; Heideman, Menounos, & Clague, 2015), trends in temperature and precipitation (Desloges, 1999; Glur, Stalder, Wirth, Gilli, & Anselmetti, 2015), and changes in the connectivity of sediment sources and sinks (Wohl, Magilligan, & Rathburn, 2017). Several researchers have studied specific sediment yield in catchments across British Columbia (Hodder et al., 2006; Heideman et al., 2015) However, fewer studies have focused on the Omineca Belt in eastern central British Columbia which is characterized by different geology and climate compared to other areas of British Columbia (Hodder et al., 2006; Menounos, Osborn, Clague, & Luckman, 2009). Collecting additional glaciolacustrine sediment stratigraphy from this region will strengthen our regional understanding of how sediment production, transport and connectivity varies across BC and better inform practitioners and policy makers.

Methods:

Thirty-four kilometres of sub-bottom acoustic records were collected across Cariboo Lake (Fig. 1).

Results:

Sub-bottom Acoustics

Acoustic stratigraphy from 6 cross-sectional transects reveal the morphology of sediment deposition in Cariboo Lake (Fig. 2). Acoustic penetration is limited in transects proximal to river deltas across Cariboo Lake. Acoustic penetration improves in areas distal from river deltas along the thalwag of acoustic transects revealing well-layered sediment deposits. Cross-hatching is observed over most of the acoustic record due to electrical interference from the research vessel but does not affect the quality of the results.

Transect A, one kilometre southwest of the Cariboo River delta, has a strong acoustic reflector along the sediment water interface indicating the presence of coarse grained material on the bed surface (Fig. 3). A high fraction of sand grains in this transect act as an acoustic mask limiting the penetration of the acoustic signal to a depth of 1-2 m along this transect. An acoustic multiple is observed 45 m below the sediment surface (Fig. 2).

Acoustically penetrable, well-layered sediment is observed 4.4 km from the Cariboo River delta in Transect C (Fig. 3). The sediment stratigraphy lies conformably over a hummocky basement (Fig. 3 xx). The acoustic basement is considered to be either bedrock or coarse-grained glacial sediment from the Last Glacial Maximum. Two sediment facies are observed across this transect based on geometry and the strength and continuity of reflectors, some disruption of these facies is caused by turbidity currents and slumping of side slopes (Fig. 3, iv). The lower unit, Facies A has a thickness of ~ 12 m along undisturbed sections (Fig. 3 iii) and may have been thicker in deeper sections before scouring by turbidity currents (Fig. 3, i and iii). Facies A is homogeneously light in color indicative of clastic-poor sediments. Distinct parallel reflectors are not observed in Facies A, yet there is a slower transition between high and low levels of reflectance. Facies B begins with the occurrence of higher amplitude parallel reflectors with 2-3 m spacing which generally conform well to Facies A outside of areas of disturbance due to slumping and turbidity currents (Fig. 3 xx). Facies B has a thickness of ~ 10 m along undisturbed sections (Fig. 3 iii) and deepens to a maximum of 13 m within the scour channels (Fig. 3, i and iii). The strength of reflectors in Facies B gradually decreases moving upwards and spacing thins to sub metre. A thick dark reflector is observed at the top of Facies B along the sediment water interface. Two sharp crested v-notch channels, not completely infilled with Holocene sediment, are inferred to be scour channels formed by past glacial activity that predates the overlying sediment (Fig. 3, i and ii). The two v-notch channels have some disturbance within the sediment layering which may be from the presence of strong turbidity currents. The acoustic record along Transect C reaches a maximum sediment thickness of 35 m, the maximum thickness of surficial sediments observed across Cariboo Lake in this study. Along the north sidewall of the Transect C sediment slumping interrupts the conformed layering of sediment to the acoustic basement. At the bottom of the transect, Sediment is conformable to the lower gradient slopes of the basin.

Transect D, to the northeast of the Frank Creek delta has good acoustic penetration and layered sediments in the top 5-10 m but transitions to an increase in acoustic masking below this (Fig. 4, i). The visible conformable parallel reflectors near the surface of Transect D have a thickness of 2-3 m and higher amplitude compared to Facies B in Transect C. The scour channels observed in Transect C, are less pronounced in this transect and suggests the scour event(s) originated from the head of the lake.

Southwest of the Frank Creek delta, acoustic reflectors along Transect E show a decline in reflectance and a decrease in layer thickness to < 1 m. Acoustic masking from course grained sediment occurs at depths of 2-4 m (Fig. 5). The sedimentary environment southwest of the Frank Creek delta is different compared to transects northeast of the delta. It appears that much of the suspended sediment transported from the Cariboo River does not make it past the shallow lake depths (< 20 m) of the Frank Creek delta. This likely results in an increase in sediment deposition northeast of the Frank Creek Delta, which may explain the increase in reflector amplitude along Transect D (Fig 4, 5).

Similar to the Frank Creek basin, the Keithley Creek basin is expected to have reduced connectivity to the main Cariboo Lake basin due to the shallow lake bathymetry (< 10 m) off the Keithley Creek delta (Fig. 1). Transect F, located close to the centre of the Keithley Creek basin shows a maximum observable sediment thickness of 4 m (Fig. 6). Below this is inferred to be an acoustic mask of courser grained sediment. The acoustic reflectors in the top 4 m of Transect F are acoustically penetrable, well layered and are conformable to the basin morphology. Reflectors are of higher amplitude compared to those in Transect E and thicker at 1-2 m. The reflectors across this transect are inferred to be primarily by sediments deposited by Keithley Creek. Due to the close proximity < 1 km to the Keithley Creek delta sediment along this transect likely have a high fraction of sand and thus limits the acoustic penetration to 4 m.

Spatial Trends

Spatial variation in surficial sediment laminae, grain size, and organic content were analyzed from 20 Ekman bulk samples (Fig. 6). Proximal to the Cariboo River delta (< 500 m) the structure of the Ekman bulk sediments exhibit massive layering, erosive contacts and the fraction of sand grains in these samples exceeds 60 %. Further from the Cariboo River delta (> 2 km) the fraction of silt grained sediments increases to over 80 %. Distinct rhythmic laminations are recognized in bulk samples at distances greater than 2.5 km from the Cariboo River delta.

Lithostratigraphy

Discussion:

Sub-bottom: The generally homacky basement of sediment across cariboo lake indicates the generally undisturbed layering of suspended sediment across the lake bottom. Transect b bottom facies not as reflective so doesn’t show up in deepest part of the basin. Bottom part of transect b and others is light in colour which is less reflective and is indicative of clastic-poor sediments which is expected during the warming period of the early Holocene. Evidence of early Holocene warming and glacial retreat is provided by various studies in the south Coast (Menounos et al., 2004; Osborn, Menounos, Koch, Clague, & Vallis, 2007; Koch, Osborn, & Clague, 2007) however some evidence of glacial advance in the Rockies has been found although the legitimacy of these radio carbon dates have been questioned in the Rockies (Menounos et al., 2009).

Transect D observes an incrwase in acoustic masks due to proximity to the frank creek delta. This is why there is less penetration on the south slope compared to the centre transect. The proximity to the Frank Creek delta here also ecplains the increase in strength of paralell reflectors due to an increase in strength of turbidity currents from Frank Creek.

Desloges, J. R. (1999). Geomorphic and climatic interpretations of abrupt changes in glaciolacustrine deposition at Moose Lake, British Columbia, Canada. *Gff*, *121*(3), 202–207.

Desloges, J. R., & Gilbert, R. (1994a). Sediment source and hydroclimatic inferences from glacial lake sediments: the postglacial sedimentary record of Lillooet Lake, British Columbia. *Journal of Hydrology*, *159*(1–4), 375–393.

Desloges, J. R., & Gilbert, R. (1994b). The record of extreme hydrological and geomorphological events inferred from glaciolacustrine sediments, (224).

Glur, L., Stalder, N. F., Wirth, S. B., Gilli, A., & Anselmetti, F. S. (2015). Alpine lacustrine varved record reveals summer temperature as main control of glacier fluctuations over the past 2250 years. *The Holocene*, *25*(2), 280–287.

Heideman, M., Menounos, B. P., & Clague, J. J. (2015). An 825-year long varve record from Lillooet Lake, British Columbia, and its potential as a flood proxy. *Quaternary Science Reviews*, *126*, 158–174.

Heideman, M., Menounos, B. P., & Clague, J. J. (2017). A multi-century estimate of suspended sediment yield from Lake, Lillooet Mountains, Coast, *32*(September 2017), 18–32.

Hodder, K. R., Desloges, J. R., & Gilbert, R. (2006). Pattern and timing of sediment infill at glacier-fed Mud Lake: Implications for lateglacial and Holocene environments in the Monashee Mountain region of British Columbia, Canada. *Holocene*, *16*(5), 705–716.

Koch, J., Osborn, G. D., & Clague, J. J. (2007). Pre-`Little Ice Age’ glacier fluctuations in Garibaldi Provincial Park, Coast Mountains, British Columbia, Canada. *The Holocene*, *17*(8), 1069–1078.

Leonard, E. M., & Reasoner, M. A. (1999). A continuous holocene glacial record inferred from proglacial lake sediments in Banff National Park, Alberta, Canada. *Quaternary Research*, *51*(1), 1–13.

Menounos, B. P., Koch, J., Osborn, G. D., Clague, J. J., & Mazzucchi, D. (2004). Early Holocene glacier advance, southern Coast Mountains, British Columbia, Canada. *Quaternary Science Reviews*.

Menounos, B. P., Osborn, G. D., Clague, J. J., & Luckman, B. H. (2009). Latest Pleistocene and Holocene glacier fluctuations in western Canada. *Quaternary Science Reviews*, *28*(21–22), 2049–2074.

Onstad, C. (1984). Sediment yield modelling. In Erosion and sediment yield: Some methods of measurement and modelling. *Geo Books*, 71–89.

Osborn, G. D., Menounos, B. P., Koch, J., Clague, J. J., & Vallis, V. (2007). Multi-proxy record of Holocene glacial history of the Spearhead and Fitzsimmons ranges, southern Coast Mountains, British Columbia. *Quaternary Science Reviews*, *26*(3–4), 479–493.

Wohl, E. E., Magilligan, F. J., & Rathburn, S. L. (2017). Introduction to the special issue: Connectivity in Geomorphology. *Geomorphology*, *277*, 1–5.